I-5
High-Occupancy Vehicle Operational Study

SUMMARY DOCUMENT

April
2000

Prepared For:
Regional Transportation Council
in cooperation with:
Washington State Department of Transportation
Oregon Department of Transportation
C-TRAN
City of Vancouver
Clark County
Metro

Submitted By:
Parsons Brinckerhoff Quade and Douglas

I-5 High-Occupancy Vehicle Operational Study Summary Document
with Technical Advisory Committee Findings

Prepared for:

Southwest Washington Regional Transportation Council

In Cooperation with:

Washington State Department of Transportation
Oregon Department of Transportation
C-TRAN
City of Vancouver
Clark County
Metro

Submitted by:

Parsons Brinckerhoff Quade and Douglas
David Evans and Associates
Pacific Rim Resources
HS Public Affairs
Innovative Transportation Concepts
HDR Engineering

April 2000

Table of Contents

Technical Appendix

List of Figures

List of Tables

EXECUTIVE SUMMARY

I. Background

The Regional Transportation Council (RTC), in conjunction with the Washington State and Oregon Departments of Transportation (WSDOT and ODOT), conducted an operational and feasibility study of High Occupancy Vehicle (HOV) lanes on I-5 between Clark County, Washington (134th Street), and Portland, Oregon. This was the next step of the Clark County Regional HOV Study, which identified a need to move forward with a more detailed feasibility and operational approach to implementing HOV facilities in the I-5 corridor. The study was charged with developing an HOV option that could be implemented in the corridor without replacing the Interstate Bridge and without the construction of any widening through Delta Park. It also follows closely the successful I-5 Northbound HOV Lane Pilot Project implemented by ODOT in October 1998. That project currently carries 2,400 persons per lane per hour, more than either of the general purpose (GP) lanes, and saves 5-7 minutes per vehicle. It also has a 70 percent public approval rating.

This effort was also strategically coordinated with the imminent construction work in Washington to widen I-5 between Main Street and 99th Street (and eventually to 134th Street) to add another lane in each direction. The study findings will provide guidance to WSDOT regarding the use of the new lane capacity.

The Base Case for this study was called the “No New HOV” alternative. It consisted of the current I-5 transportation network and projects contained in the Metropolitan Transportation Plan (MTP) outside of the I-5 Corridor. It also included the I-5 widening in Washington and the existing northbound HOV lane between Going Street and Delta Park in Oregon that operate during the PM peak period only. During the study process, several HOV strategies and alternatives were developed and considered. These included Queue Bypass options (no HOV on the Interstate Bridge, HOV lanes at selected locations in Washington and/or Oregon), a Delta Park only option (AM peak period), and a Full Corridor option which carried reversible HOV lanes across the Interstate Bridge.

A public opinion survey of 800 Clark County residents was conducted as part of the I-5 HOV Operational Study. The survey provided representative data of attitudes, knowledge, and behavior regarding HOV lanes.

The survey concluded that almost all bi-state travelers (96%) were aware of the existing northbound I-5 HOV lane. Two-thirds of those using the HOV lane reported saving travel time.

Slightly more than 50 percent supported HOV lanes as an effective traffic management strategy. Most respondents (59%) favored implementing HOV by adding the lane instead of converting an existing general purpose lane for HOV. Two-thirds supported peak-period operation of HOV lanes, while 23 percent supported 24-hours-a-day, 7-days-per-week operation of the HOV lane. Most of those surveyed (80%) agreed that the HOV lanes should have a strong enforcement program.

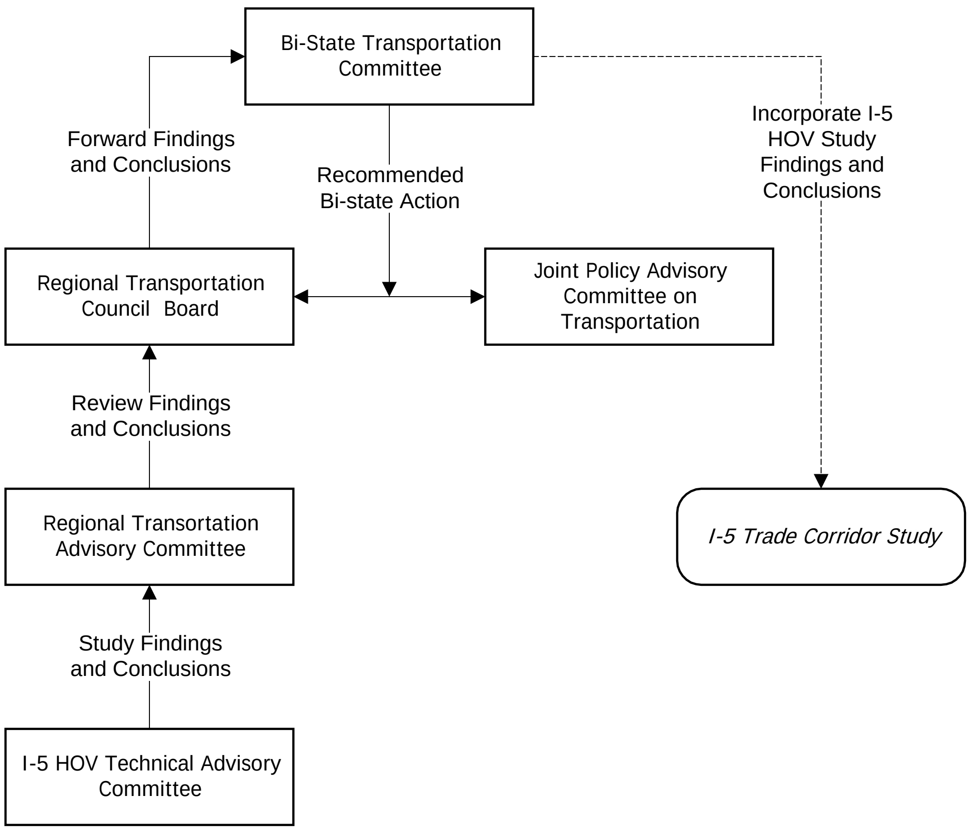
II. Decision-Making Process

RTC was the project lead for the overall study and the management of work tasks. The I-5 HOV Technical Advisory Committee provided expertise and comment on the technical analysis and was made up of staff from the Washington State Department of Transportation, City of

Vancouver, Clark County, C-TRAN, Metro, and the Oregon Department of Transportation. In addition, the two state transportation departments provided expert advice regarding the operation, design, and characteristics on HOV and their state facilities. Findings and recommendations of the TAC were forwarded to the Regional Transportation Advisory Committee for their comment and review prior to consideration by the RTC Board.

The RTC Board received the study finding and conclusions and forwarded them to the Bi-State Transportation Committee for their discussion. The role of the Bi-State Transportation Committee was to consider the study findings and conclusions and to recommend any bi-state action to the RTC Board and Joint Policy Advisory Committee on Transportation (JPACT) regarding an HOV facility in the I-5 corridor. Study findings will be forwarded to the I-5 Trade Corridor Study.

Figure ES-1. Decision-Making Process



III. Selected HOV Option

After analysis and screening of several HOV options in the I-5 corridor, three non-bridge HOV options were evaluated for detailed operational analysis: Washington only HOV, Oregon only HOV and a bi-state HOV option consisting of an HOV facility in Washington and Oregon with no HOV on the Interstate Bridge. All HOV options resulted in travel time savings and higher HOV person demand than the base case, which has no AM southbound HOV. However, of the three options, the bi-state HOV option offered the highest travel time savings and HOV person demand. A bi-state HOV facility in the I-5 corridor resulted in significant mobility improvement in the corridor for transit and other shared ride users.

The selected bi-state HOV option developed in the I-5 corridor is based on an analysis of traffic operations, safety, and design issues for the HOV options studied. The PM HOV option consists of the current NB HOV lane between Going Street and Marine Drive. The AM HOV option consists of a southbound HOV facility in Washington from 134th Street to Mill Plain Boulevard, no HOV lane across the Interstate Bridge, and an HOV lane in Oregon from Marine Drive to Lombard Avenue. The southbound AM option is described below:

WASHINGTON

- *Two general-purpose travel lanes plus an HOV lane from 134th Street to SR 500*. This would also include an auxiliary add/drop lane from 134th Street to SR 500.
- *Added capacity for HOV from SR 500 to Mill Plain Boulevard*. This would be accomplished by reconfiguration of the existing lane and shoulder striping to provide an additional through (HOV) lane in this segment. There are two possible design options for this reconfiguration:
    - a new outside general purpose lane would be added from SR 500 south to the Interstate Bridge and the inside general purpose lane would be utilized for HOV; the HOV lane designation would drop at Mill Plain Boulevard to allow all vehicles to use the inside lane across the bridge; or
    - An HOV lane would be added to the inside median which would then merge with general purpose traffic before crossing the Interstate Bridge. The tradeoffs between the two design options have been defined and should be considered in the decision-making process for HOV implementation.

Interstate Bridge *No HOV lane across the bridge*.

OREGON

Added capacity for HOV from Marine Drive to Lombard Avenue. The I-5 HOV Operational study's original goal was to analyze the feasibility of implementing an HOV lane without widening the corridor through Delta Park. The study examined accomplishing this via a reversible lane using a movable barrier. While the construction cost for such a concept would be lower than the cost of widening, ongoing operations and maintenance costs may eventually result in higher overall costs for the reversible lane compared to widening. It was determined that HOV should not be implemented without a major widening of the corridor due to overall cost, safety, and operational concerns. Southbound HOV capacity should be provided by constructing an additional travel lane on Interstate 5 from the Delta Park interchange to Lombard Ave. This project is included in the Metro's Regional Transportation Plan (RTP) strategic plan and ODOT has begun preliminary work on the project. The project was also recommended by the I-5 Trade Corridor Leadership Committee.

PERFORMANCE OF SELECTED HOV ALTERNATIVE

The selected southbound HOV option compares favorably against the following performance measures:

- HOV would save users one minute per mile and a minimum of 5 minutes overall (meets the total travel times savings, but not travel time savings per mile in 2003, well-met in 2020)
- HOV lane is forecast to carry at least 600 vehicles per hour (would be met southbound in the opening year (2003) as well as in 2020)

- The HOV lane is expected to carry more persons per hour than any adjacent GP lane (would be met southbound in 2003 as well as in 2020)
- General purpose lanes are currently experiencing LOS E/F conditions for at least one peak hour in each peak direction.

IV. Key Findings

Of the HOV options identified for detailed analysis, the bi-state HOV option had the most benefit to mobility in the I-5 corridor, by providing the highest travel time savings and HOV person demand. The analysis results are summarized in the following table:

AM 2 Hour: Summary of HOV Options[1]						
Alternative	**Vehicles in HOV Lane**	**Bus Ridership**	**Persons in HOVs**	**Persons per GP lane**	**HOV Lane Time Savings (Minutes per Vehicle**	**HOV Lane Time Savings (Minutes per Mile)**
Base-Case: No New HOV	N/A	1,720	4,000	----	-----	N/A
Washington-only	1,400[2]	1,800	4,900	3,850	7-8	1.1
Oregon only HOV	1,000	1,760	4,370	3,600	1.8	0.7
HOV in Washington and Oregon	***1,530***	***1,900***	***5,120***	***3,850***	***8-10***	***1.1 – 1.2***

1. Measured at Marine Drive
2. Measured at Mill Plain Boulevard

In addition, the study finds that:

- A Bi-State I-5 HOV facility provides the greatest mobility by increasing the number of persons using the corridor and reducing overall vehicle hours of travel compared to other HOV alternatives and to the provision of general purpose capacity.
- The study findings are consistent with the adopted MTP and the Clark County HOV Study (December 1998).
- The I-5 Corridor is a National Priority Trade Corridor and HOV facilities should be considered within the context of the overall function of I-5 and considered further during the development of the I-5 Corridor Development and Management Plan.
- Persons using the HOV lane exceed the number of persons per lane in the adjacent general purpose lane.
- HOV lanes show significant travel time savings for HOV users.
- Southbound between SR 500 and the Interstate Bridge, HOV scenarios which added a lane rather than converting an existing lane showed less congestion.

- In 2020, southbound AM peak congestion occurs for most of the corridor between 134th Street and the Interstate Bridge.
- The Interstate Bridge is the most significant bottleneck in the corridor. The bridge affects peak-hour traffic causing significant queuing which will grow worse by 2020.
- In the southbound direction, the bottleneck at the Interstate Bridge is exacerbated by another bottleneck downstream at Delta Park. The combination of these two bottlenecks causes significant queuing.
- Approximately one mile of queuing, similar to that currently experienced, is expected through Delta Park in 2020.
- A review of HOV alternatives shows a southbound HOV lane between 134th Street and the Interstate Bridge and through Delta Park saves HOV users approximately 8 to 10 minutes per vehicle compared to general purpose lanes, and over one minute per mile.
- Most of the projected HOV time savings occurs in Washington (7-8 minutes per vehicle).
- Southbound travel time savings through Delta Park is limited by the capacity constraints at the Interstate Bridge.
- The northbound PM peak reversible HOV lane across the Interstate Bridge significantly increases congestion in the southbound direction in 2020 due to the loss of a southbound general purpose lane.
- Benefits gained by having a northbound reversible HOV lane on the southbound span of the Interstate Bridge are more than offset by the disbenefits of increased congestion in the southbound direction in the PM peak period.
- Any reversible lane option on the Interstate Bridge reduces travel lane width, impacts traffic operations, and is difficult to design and manage with an operating lift-span drawbridge.
- A reversible lane through Delta Park was a design option working within the existing bridge structures over the Columbia Slough and Columbia Boulevard. The substandard nature of its design, including lack of shoulders and left-hand merging areas, presents significant safety and operational concern. In addition, the project requires a $6 million capital cost and annual operating costs of $750,000.
- The cost to implement HOV in Washington is approximately $362,000.

<u>The study concluded that:</u>

- No further consideration should be given for a PM peak northbound HOV lane in Washington unless warranted by congestion or if new capacity is provided by a replacement of the Interstate Bridge.
- No further consideration should be given for a reversible HOV facility across the existing Interstate Bridge spans.
- A minimum of three general purpose lanes should be provided in each direction in Washington between SR 500 and the Interstate Bridge.
- Although the selected HOV option north of SR 500 is 2 general purpose lanes plus an HOV lane, the conversion to 3 general purpose travel lanes plus and an HOV lane should considered when warranted by congestion or when new bi-state capacity is provided by the replacement of the Interstate Bridge.
- A southbound, AM peak period HOV lane through Delta Park should be accomplished via widening of the corridor to achieve three full-time through lanes within acceptable design standards rather than by a peak-only reversible lane.

- Widening of I-5 southbound through Delta Park would provide AM peak period HOV capacity and non-peak freight capacity.

The I-5 Trade Corridor Study's Corridor Development and Management Plan should address these conclusions as part of the overall Bi-State decision-making process on the I-5 corridor, including the considerations for any new Columbia River crossing capacity. A summary matrix of the study findings and conclusions by segment is included at the end of the executive summary.

The following Agency Issues will need discussion and resolution prior to further consideration of an HOV configuration in the corridor:

- The implementation of an I-5 Bi-State HOV Corridor will require bi-state consensus.
- The study findings should be considered in the context of the current I-5 widening construction project between 99th Street and SR 500.
- The study findings should be advanced through the decision-making process, including the I-5 Trade Corridor Study.
- Lane configurations inclusive of HOV on southbound I-5 from SR 500 to the Interstate Bridge require resolution of design issues.
- Design of HOV southbound through Delta Park requires resolution of design issues to determine how an HOV lane through Delta Park should be implemented as part of major widening through Delta Park.
- The analysis results for a reversible lane concept in Oregon should be forwarded for consideration in the Delta Park widening discussions.
- The I-5 HOV Operational Study findings are consistent with WSDOT HOV policy regarding travel time savings, lane use, added capacity for HOV and segment length, but not time-of-day operation.

V. Bi-State Policy Issues

- An Intergovernmental agreement between RTC and Metro states that JPACT and RTC Board, "Metro and RTC shall take no action on an issue of bi-state significance without first referring the issue to the Bi-State Transportation Committee for their consideration and recommendation." The findings of the I-5 HOV Operational Study is being forwarded to the Bi-State Transportation Committee for their discussion and recommendation. Any recommended action by the Bi-State Transportation Committee will go to RTC and JPACT for their consideration.
- The I-5 HOV Operational Study identifies HOV as a viable short-term strategy; it does not address the HOV in the corridor with an Interstate Bridge replacement. The I-5 Trade Corridor Study will be addressing the long-term role of HOV in the corridor in the context of new bridge capacity. The study findings and conclusions should be forwarded to the I-5 Trade Corridor Study process.
- The study findings must be considered in the context of the current I-5 widening construction project north of SR 500. Study findings will provide guidance to WSDOT regarding the use of new lane capacity currently being constructed.
- The I-5 HOV Operational Study findings are consistent with WSDOT HOV policy regarding travel time savings, lane use, added capacity for HOV and segment length. State policy calls

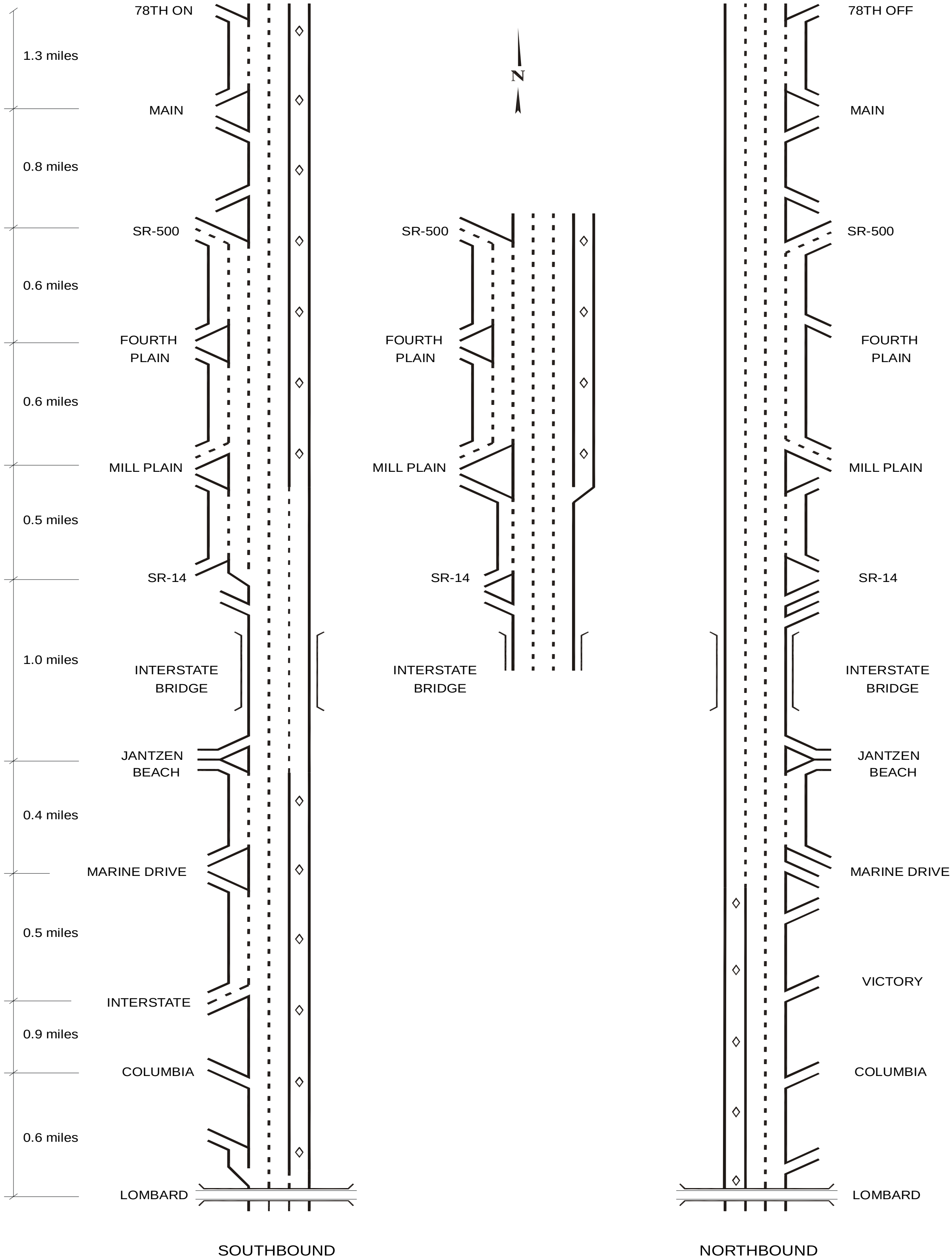
for full time HOV lane operation. However, the study recommends peak period only HOV in the I-5 corridor.

- Funding to implement the widening to accommodate HOV through Delta Park should be considered in the Bi-State funding discussions for the I-5 corridor.

Table ES-1. Summary of I-5 HOV Operational Study Findings and Conclusions

Finding	Conclusion
Bi-State Corridor	
Bi-State I-5 HOV facility provides the greatest mobility of all alternatives studied.	A southbound, AM peak period HOV facility should be provided in the I-5 Bi-State corridor. In the PM peak, the current northbound HOV lane between Going Street and Delta Park is preferred.
The I-5 Corridor is a National Priority Trade Corridor and HOV facilities should be considered within the context of the overall function of I-5.	The I-5 Trade Corridor Study should receive and address these findings as part of the overall Bi-State decision-making process on the I-5 corridor.
Washington Portion	
In 2020, southbound AM peak congestion occurs for most of the corridor between 134th Street and the Interstate Bridge.	The selected HOV option consists of an AM southbound HOV facility from 134^{th} Street to Mill Plain Boulevard.
A southbound HOV lane between 134^{th} Street and the Interstate Bridge and through Delta Park is projected to save HOV users approximately 8 to 10 minutes per vehicle compared to general purpose lanes in 2020, and over one minute per mile. Most of the projected HOV time savings occurs in Washington (7-8 minutes per vehicle).	The minimum operable segment in the AM peak is from 78^{th} Street to Mill Plain Boulevard.
The Interstate Bridge meters traffic in each direction, affecting downstream queues both currently and in 2020.	No further consideration should be given for a northbound HOV lane in the PM peak on the Washington side. A northbound HOV lane north of the Interstate Bridge should be considered when congestion levels warrant an HOV lane or if and when the Interstate Bridge is replaced.
Interstate Bridge	
The Interstate Bridge meters traffic in each direction, affecting downstream queues both currently and in 2020.	The I-5 Trade Corridor Study should receive and address these HOV considerations for any new Columbia River crossing capacity.
Benefits gained by having a northbound reversible HOV lane on the Interstate Bridge are more than offset by the disbenefits of increased congestion in the southbound direction in the PM peak period.	No further consideration should be given for a reversible HOV facility across the Interstate Bridge.
Any reversible lane option on the Interstate Bridge reduces travel lane width, impacts traffic operations, and is difficult to design and manage with an operating lift-span drawbridge.	No further consideration should be given for a reversible HOV facility across the Interstate Bridge.
Oregon Portion	
Approximately one mile of queuing, similar to that currently experienced, is expected through Delta Park in 2020.	Design of HOV southbound through Delta Park requires resolution of design issues and the implementation of HOV through Delta Park should be implemented as part of major widening through Delta Park.
A reversible lane design option through Delta Park has a substandard design, lack of shoulders and left-hand merging areas, presenting significant safety and operational concerns along with significant ongoing operational costs.	A southbound, AM peak period HOV lane through Delta Park should be accomplished via widening of the corridor to achieve three full-time through lanes within acceptable design standards.

Figure ES2. Selected HOV Configuration



STUDY PROCESS

Introduction

RTC, in conjunction with WSDOT and ODOT, conducted an operational and feasibility study of High Occupancy Vehicle (HOV) lanes on I-5 between Portland, Oregon, and Clark County, Washington (134th Street). This was the next step of the Regional HOV Study, which identified a need to move forward with a more detailed feasibility and operational approach to implementing HOV facilities in the I-5 corridor. It also followed closely the successful HOV lane Pilot Project implemented by ODOT in October 1998. That project currently carries 2,400 persons per lane per hour, more than either of the general purpose lanes, and saves 5-7 minutes per vehicle. It also has a 70 percent public approval rating.

The partner agencies involved with this study, RTC, WSDOT, ODOT, Metro, C-TRAN, and local jurisdictional staff, are already engaged in discussions about traffic and mobility issues on the I-5 corridor through several current projects. These include the I-5 Trade Corridor Study, the I-5/I-205 North Corridor Study, the I-5 HOV Pilot Project, and the Interstate Bridge Traffic Management Plan. Each of these forums have discussed implementing HOV in the I-5 corridor. Building on momentum gained by the HOV discussions at these forums, the region will continue to engage these agencies in discussing the implementation of HOV in the I-5 corridor.

The Study charge was to *examine the feasibility of implementing HOV in the I-5 corridor without replacing the Interstate Bridge*. This effort was also strategically coordinated with the imminent construction work to widen I-5 in Washington between Main Street and 99th Street (and eventually to 134th Street) to add another lane in each direction. The study findings will provide guidance to WSDOT regarding the use of the new lane capacity.

The I-5 HOV Operational Study was conducted within the context of ongoing planning efforts in the I-5 corridor, and with sensitivity for the issues and concerns of local agencies, the general public, and other corridor stakeholders.

Several key issues were identified early in the study process. These were:

- Previous analysis and evaluation conducted for ODOT indicated that HOV lanes across the Interstate Bridge should be accompanied by added capacity, rather than converting an existing lane in the peak direction.
- An earlier study on the southbound HOV lane in Oregon through the two-lane section in Delta Park indicated that a simple restriping is not feasible due to substandard merge areas.
- Whether or not the HOV lane demand would be able to satisfy desired HOV thresholds of 400-500 vehicles per hour.
- How to implement a reversible HOV lane across the Interstate Bridge, given the narrow roadway width between barriers and that the bridge is a drawbridge.
- Oregon and Washington have different HOV policies regarding the time of HOV operation.
- Coordinating HOV recommendations with the I-5 Trade Corridor Study being conducted simultaneously.

A Bi-State Technical Advisory Committee (TAC), comprised of representatives from RTC, WSDOT, ODOT, Metro, C-TRAN, City of Vancouver, and Clark County, some of whom are also involved with the I-5 Trade Corridor Study, was established to provide for coordination on multiple levels to address, and to resolve, these issues.

Study Process

The Study Corridor consists of I-5 between I-205 in north Vancouver and I-405 in Portland (see **Figure 1**). The analysis years were 2020 (long-term) and 2003 (short-term and opening year).

Figure 2 shows the overall process flow for the study. The study was conducted in two phases:

Phase I (HOV Feasibility Analysis) consisted of assembling information existing and future conditions, establishing a base case to be used for comparison of HOV alternatives, developing a range of HOV options, assessing risk and resolving physical issues to determine the feasibility of HOV alternatives, and selecting a set of HOV strategies to be carried forward into Phase II for more detailed analysis.

Phase II (HOV Evaluation and Selection of Selected HOV Alternative) consisted of developing conceptual engineering drawings of the HOV alternatives, evaluating the HOV alternatives, and selecting a preferred HOV alternative. Short- and long-term operational analysis was conducted to assist in the evaluation.

The completion of Phase II represents the end of the technical work of the study. The policy decision-making process on whether to implement HOV in the I-5 corridor will occur in 2000.

During the course of the study, a Peer Review process was used and a continuous public outreach program was conducted, which included a public opinion survey. These are described in detail later in this report.

Outcomes

SOUTHBOUND FINDINGS

The study found that a Bi-State I-5 HOV facility provides the greatest mobility by increasing person throughput and reducing overall vehicle hours of travel compared to all other alternatives. Southbound, HOV users are projected in the Year 2020 to save approximately 8 to 10 minutes per vehicle compared to general purpose lanes, and over one minute per mile, with most of the projected HOV time savings occurring in Washington (7-8 minutes per vehicle), for any of the HOV alternatives. Southbound between SR 500 and the Interstate Bridge, HOV scenarios that added a lane rather than converting an existing lane showed less congestion. Southbound travel time savings through Delta Park is limited due to the capacity constraints of the Interstate Bridge; approximately one mile of queuing, similar to that currently experienced, is expected through Delta Park in 2020, limiting the HOV time savings to approximately 1-2 minutes per vehicle.

Figure 1.   I-5 HOV Operational Study Corridor

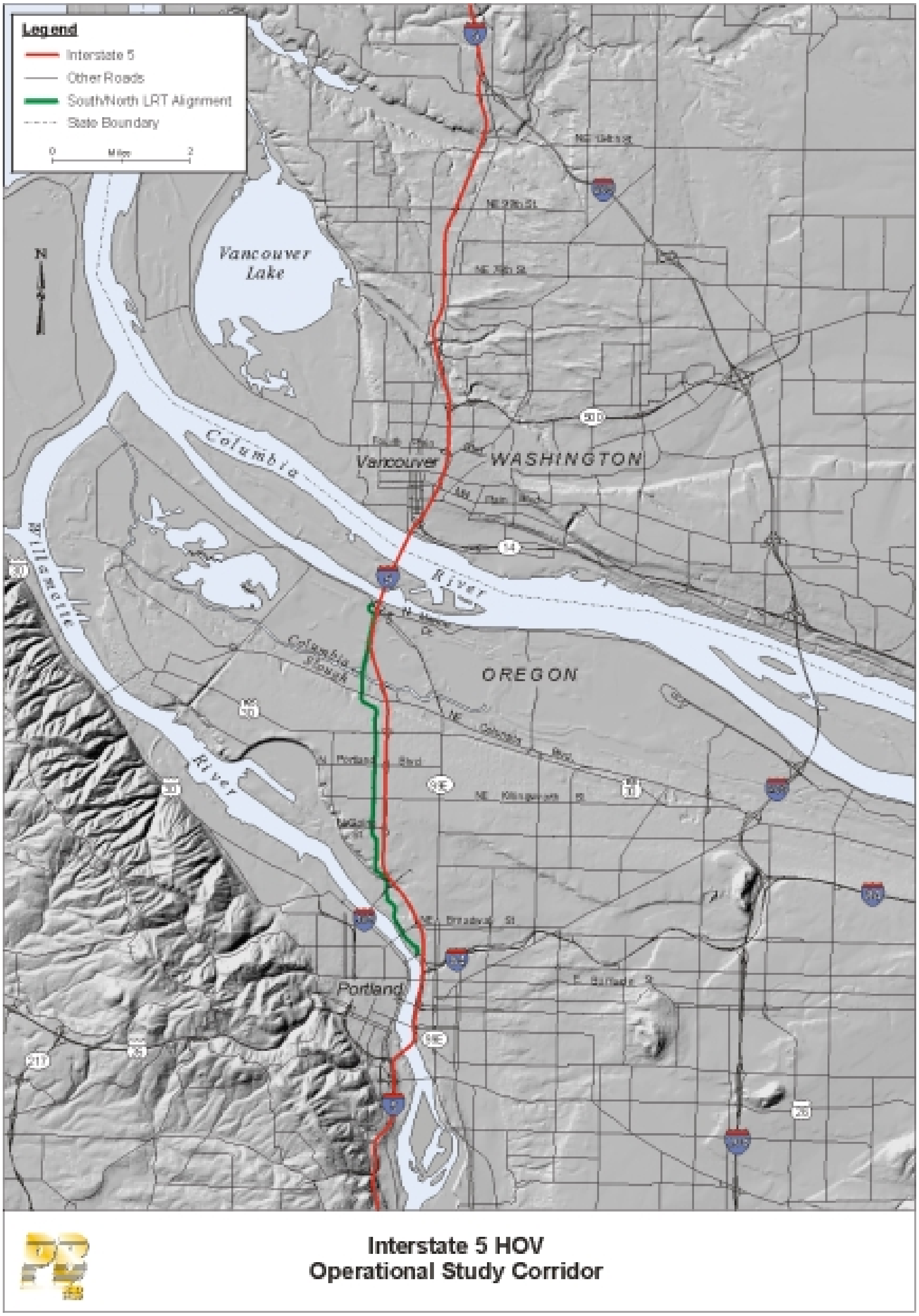
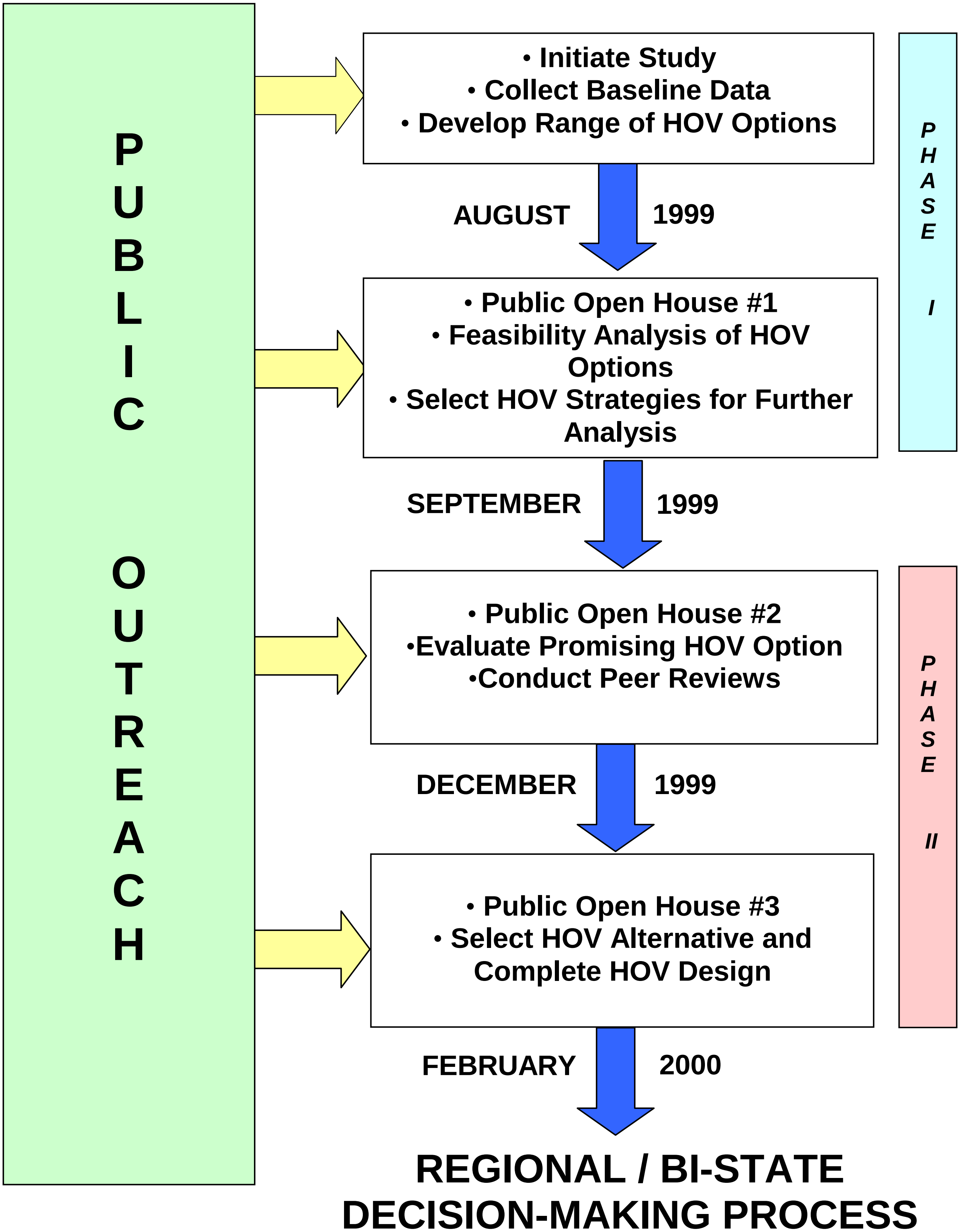


Figure 2. I-5 HOV Operational Study Process Flow



TAC CONCLUSION FOR SOUTHBOUND I-5

It was concluded by the TAC that a southbound, Bi-State HOV facility provides the maximum mobility in terms of person throughput, and that through Delta Park the HOV lane should be implemented by way of an additional travel lane (HOV in the AM peak period, general purpose at other times) instead of installing a reversible lane in the current section, due to safety, design, and operational cost concerns.

NORTHBOUND FINDINGS

Northbound, HOV users are projected in the Year 2020 PM peak to save 9 to 10 minutes per vehicle compared to the general purpose lanes, with virtually all of the time savings occurring in Oregon. The Interstate Bridge meters traffic in each direction, affecting downstream queues both currently and in 2020, which minimizes HOV time savings through Delta Park in the AM peak and on the Washington side of the Columbia River in the PM peak.

TAC CONCLUSION REGARDING NORTHBOUND I-5

The TAC concluded that in the PM peak, the current northbound HOV lane between Going Street and Delta Park is preferred and that, at this time, no further consideration should be given for a northbound HOV lane in the PM peak on the Washington side. Northbound north of the Interstate Bridge HOV should be considered when congestion levels warrant an HOV lane or if and when the Interstate Bridge is replaced.

INTERSTATE BRIDGE FINDINGS

Regarding the Interstate Bridge, a northbound PM peak reversible lane across the Interstate Bridge significantly increases congestion in the southbound direction in 2020 due to the loss of a southbound lane. Benefits gained by having a northbound reversible HOV lane on the Interstate Bridge are more than offset by the disbenefits of increased congestion in the southbound direction in the PM peak period. Any reversible lane option on the Interstate Bridge reduces travel lane width, impacts traffic operations, and is difficult to design and manage with an operating lift-span drawbridge.

TAC CONCLUSIONS REGARDING THE INTERSTATE BRIDGE

The TAC concluded that no further consideration should be given for a reversible HOV facility across the existing Interstate Bridge. Northbound north of the Interstate Bridge, three general purpose travel lanes and an HOV lane should considered when warranted by congestion or when the Interstate Bridge is replaced. Additionally, the TAC recommended that the I-5 Trade Corridor Study should receive and address these conclusions as part of the overall Bi-State decision-making process on the I-5 corridor, including the considerations for any new Columbia River crossing capacity.

Description of Selected HOV Option

The selected HOV option consists of an AM southbound HOV facility in Washington from 134th Street to Mill Plain Boulevard, no HOV lane across the Interstate Bridge, and added capacity for an HOV from Marine Drive to Lombard Avenue.

WASHINGTON

- *Two general-purpose travel lanes plus an HOV lane from 134th Street to SR 500*. This would also include an auxiliary add/drop lane from 134th Street to SR 500.
- *Added capacity for HOV from SR 500 to Mill Plain Boulevard*. This would be accomplished by reconfiguration of the existing lanes and shoulder striping to provide an additional through (HOV) lane in this segment. There are two possible design options for this reconfiguration:
  - A new outside general purpose lane would be added from SR 500 south to the Interstate Bridge and the inside general purpose lane would be utilized for HOV; the HOV lane designation would drop at Mill Plain Boulevard to allow all vehicles to use the inside lane across the bridge; or
  - An HOV lane would be added to the inside median which would then merge with general purpose traffic before crossing the Interstate Bridge. The tradeoffs between the two design options have been defined and should be considered in the decision-making process for HOV implementation.

INTERSTATE BRIDGE

No HOV lane across the bridge.

OREGON

Added capacity for HOV from Marine Drive to Lombard Avenue. Southbound capacity is provided through widening Interstate 5 to three lanes from the Delta Park interchange to Lombard Ave. This project is included in the RTP strategic plan and ODOT has begun preliminary work on the project. The project was also recommended by the I-5 Trade Corridor Leadership Committee.

Decision-Making Process

The HOV findings, Final Report, and TAC action will be forwarded to the Bi-State Committee, RTC Board, and JPACT for their review and action. It is expected that the HOV findings will be forwarded to the I-5 Trade Corridor Study for incorporation into the long-range corridor discussions currently underway in the corridor.

The ultimate implementation of HOV in the corridor will be the responsibility of WSDOT and ODOT.

ALTERNATIVES DEVELOPMENT AND FEASIBILITY ANALYSIS

Overview

Phase I of the study developed a range of HOV alternatives and assessed the feasibility of these alternatives. The goal was to narrow the range of options to a set of promising HOV alternatives that were evaluated during Phase II. Building upon previous work conducted in the corridor, a multi-agency brainstorming process was used to develop the range of HOV alternatives. The feasibility of each HOV alternative was reviewed by conducting a risk assessment and physical issues resolution process.

Conceptual engineering of various HOV configurations, and demand and operational model runs produced before or early in the study assisted in the feasibility analysis. Corridor queuing and operational models were calibrated during this study phase for use in Phase II.

A Peer Review Panel comprised of nationally-recognized experts in the area of HOV systems planning and development as well as representatives of public agencies which operate HOV systems, including movable barrier, reversible HOV lanes was established. The panel reviewed the results of the feasibility analysis and commented on the range of HOV options. The Peer Review process was used by the Technical Advisory Committee to narrow the range of options to a set of promising HOV strategies.

Development of a Range of Alternatives

To begin developing a range of HOV alternatives, a brainstorming meeting was held with members of the I-5 HOV Operational Study Technical Advisory Committee; WSDOT and ODOT Design, Planning, Traffic, and Bridge Engineering Staff; representatives from the Oregon and Washington districts of the Federal Highway Administration, and consultant team members. The meeting purpose was to develop a range of feasible HOV options in the I-5 corridor between I-405 in Portland and NE 134th Street in Vancouver, without replacement of the Interstate Bridge.

Previous analysis in the corridor indicated that converting an existing general purpose lane to an HOV lane would increase congestion levels and delay in the corridor. The previous southbound HOV analysis indicated short sections of HOV facilities provided by lane conversion would worsen the current conditions. This previous analysis was presented at the brainstorming meeting.

Table 1 below lists the range of alternatives generated from that meeting.

Table 1. Range of HOV Alternatives

Alternative	Start	End	Oregon Treatment	Washington Treatment	Bridge Treatment	Comments
No-Action	Going	Marine Drive	Northbound only	None	None	Base Case
1	Going	134th Street	2GP+HOV northbound only	3GP + HOV northbound only	Reversible, contra-flow HOV northbound only	3GP+HOV over length of reversible lane. Check impact on southbound traffic. 99th to 134th widening is Post 2005.
2	Going	134th Street	3GP + HOV (reversible)	3GP + HOV (reversible)	Reversible, contra-flow HOV	Check weaving. 99th to 134th widening outside of 6-year period.
3	134th Street	Before Bridge	None in AM (Base case for PM)	2GP + HOV (southbound only)	None	Check what happens in Delta Park. 99th to 134th widening outside of 6-year period.
4a	134th Street	Going or Portland Blvd.	2GP+Reversible HOV in Delta Park	2GP + HOV	Reversible, contra-flow HOV	Check for access. May answer questions about additional capacity needs in Delta Park. southbound reversible lane may have positive separation difficulties. 99th to 134th widening outside of 6-year period.
4b	134th Street	Going or Portland Blvd.	2GP+Reversible HOV in Delta Park	3GP + HOV	Reversible, contra-flow HOV	Check for access. May answer questions about additional capacity needs in Delta Park. southbound reversible lane may have positive separation difficulties. 99th to 134th widening outside of 6-year period.
4c	134th Street	Going or Portland Blvd.	2GP+Reversible HOV in Delta Park	4GP + reversible HOV	Reversible, contra-flow HOV	Check for access. May answer questions about additional capacity needs in Delta Park. southbound reversible lane may have positive separation difficulties. 99th to 134th widening outside of 6-year period.
4d	134th Street	Going or Portland Blvd.	2GP+HOV (widening in Delta Park southbound)	2GP or 3GP + HOV	None	Check for access and merging at end of HOV lane. May answer questions about additional capacity needs in Delta Park. 99th to 134th widening outside of 6-year period.

Alternative	Start	End	Oregon Treatment	Washington Treatment	Bridge Treatment	Comments
5	Going	134th Street	2GP+HOV (northbound only) - existing HOV lane	2GP or 3GP + HOV (northbound only)	None	Check for access and merging at end of HOV lane. 99th to 134th widening outside of 6-year period.
No HOV	Going	134th Street	None	None	None	No-HOV alternative. This will be modeled through the Trade Corridor Study and an analysis included in the HOV study.
6a	Marine	Mill Plain	3GP to Marine Drive; 3GP+Reversible HOV from Marine Drive north (northbound only)	3GP + Reversible HOV from Bridge to near Mill Plain	Reversible, contra-flow HOV	Reverts current HOV lane to GP. Allows check of impacts of reversible HOV on bridge.
6b	Going	Mill Plain	3GP+Reversible HOV from Going to Marine (northbound only)	3GP + Reversible HOV from Bridge to near Mill Plain	Reversible, contra-flow HOV	Retains current HOV lane. Allows a second check of impacts of reversible HOV on bridge.
7	Marine	Going or Portland	Use current HOV lane as reversible	None	None	May have positive separation difficulties southbound.
8	Going	134th Street	Current HOV from Going to Marine Drive; add HOV ramp meter bypasses	HOV ramp meter bypasses (none currently planned)	None	TSM option
9	134th Street	Going or Portland	Reversible, express HOV lane	Reversible, express HOV lane	Reversible, express HOV lane	No access between begin and endpoints. Need to examine incidents and breakdowns.
10	134th Street	Going or Portland	2GP+HOV northbound; 1/2GP + HOV (lane conversion) southbound	Convert left lane to HOV	Convert left lane to HOV	No access between begin and endpoints. Need to examine incidents and breakdowns.

Feasibility Analysis

The Feasibility Analysis consisted of the following steps:

- Examining the range of options for combining into common HOV strategies
- Reviewing using previously generated information to determine if HOV strategies could be discarded
- Conducting a Risk Assessment and identifying physical issues that would need to be resolved if certain HOV strategies are carried forward. If the risk is high, or if the physical issue cannot be resolved, then the candidate HOV strategy should be eliminated.

Using information assembled from previous studies, traffic and occupancy counts, and knowledge of other HOV systems, the range of HOV alternatives was screened for feasibility.

Table 2 summarizes the results of the first-level screening.

Table 2. First Level Screening of HOV Alternatives

Alternative	Comments	Recommendation
No-Action	Base Case	**Keep – becomes Alternative #1**
1	3GP+HOV over length of reversible lane. Check impact on southbound traffic. 99th to 134th widening outside of 6-year period.	Merge with 4a or 4b to make two-directional
2	Check weaving. 99th to 134th widening outside of 6-year period.	Discard - reversible lane too long
3	Check what happens in Delta Park. 99th to 134th widening outside of 6-year period.	Keep to analyze as queue bypass alternative
4a	Check for access. May answer questions about additional capacity needs in Delta Park. Southbound reversible lane may have positive separation difficulties. 99th to 134th widening outside of 6-year period.	**Keep – becomes Alternative #2**
4b	Check for access. May answer questions about additional capacity needs in Delta Park. Southbound reversible lane may have positive separation difficulties. 99th to 134th widening outside of 6-year period.	**Keep – becomes Alternative #3 (2 GP + HOV in WA) and #4 (3 GP + HOV in WA)**
4c	Check for access. May answer questions about additional capacity needs in Delta Park. Southbound reversible lane may have positive separation difficulties. 99th to 134th widening outside of 6-year period.	Discard – modeling does not show a capacity need for five lanes north of the Columbia River.
4d	Check for access and merging at end of HOV lane. May answer questions about additional capacity needs in Delta Park. 99th to 134th widening outside of 6-year period.	**Keep – becomes Alternative #5 (2 GP + HOV in WA) and #6 (3 GP + HOV in WA)**
5	Check for access and merging at end of HOV lane. 99th to 134th widening outside of 6-year period.	Merge with 4a or 4b to make two-directional
No HOV	No-HOV alternative. This will be modeled through the Trade Corridor Study and an analysis included in the HOV study.	Discard - will be analyzed through Trade Corridor Study
6a	Reverts current HOV lane to GP. Allows check of impacts of reversible HOV on bridge.	Discard - alternative 4a will allow us to examine scaled back HOV alternative
6b	Retains current HOV lane. Allows a second check of impacts of reversible HOV on bridge.	Discard - alternative 4a will allow us to examine scaled back HOV alternative
7	May have positive separation difficulties southbound.	**Keep – becomes Alternative #7**
8	TSM option	**Keep – becomes Alternative #8**
9	No access between begin and endpoints. Need to examine incidents and breakdowns.	Discard - reversible lane too long
10	No access between begin and endpoints. Need to examine incidents and breakdowns.	Discard - previous analysis indicates would worsen congestion over base case

This resulted in eight HOV alternatives being carried forward into the next stage of the Feasibility Analysis: Risk Assessment, Physical Issues Resolution, and Peer Review. The eight alternatives are:

1. Base Case (No New HOV): Retain current northbound PM peak period HOV lane
2. Queue Bypass #1: Alternative #1 plus an AM peak period HOV queue bypass between 134th Street and the Interstate Bridge
3. Full Corridor Option A: HOV lanes in each direction between Going Street and 134th Street with reversible HOV lane on the Interstate Bridge (Washington: 2 GP + HOV designation)
4. Full Corridor Option B: HOV lanes in each direction between Going Street and 134th Street with reversible HOV lane on the Interstate Bridge (Washington: 3GP + HOV designation)
5. Queue Bypass #2a: HOV lanes in each direction between Going Street and 134th Street with no HOV lane on the Interstate Bridge (Washington: 2GP + HOV designation; Oregon: widen southbound in Delta Park)
6. Queue Bypass #2b: HOV lanes in each direction between Going Street and 134th Street with no HOV lane on the Interstate Bridge (Washington: 3GP + HOV designation; Oregon: widen southbound in Delta Park)
7. Delta Park only: Oregon-only HOV lane (use current lane in Delta Park as reversible)
8. Alternative #1 plus HOV ramp meter bypasses in the I-5 corridor

These are graphically depicted in **Figures 3 through 10**.

Figure 3. HOV Alternative 1 – No New HOV

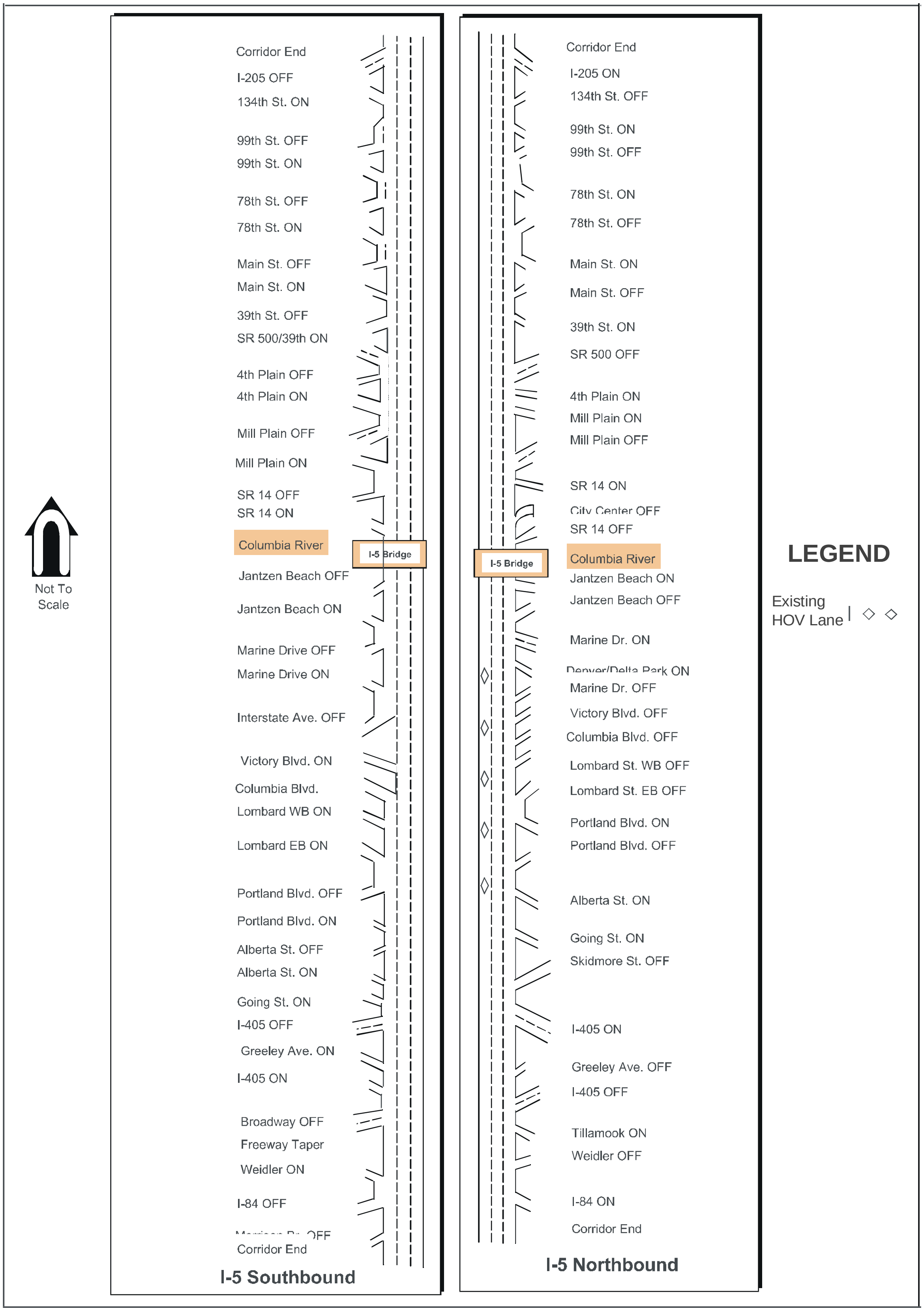


Figure 4. HOV Alternative 2 – Queue Bypass #1

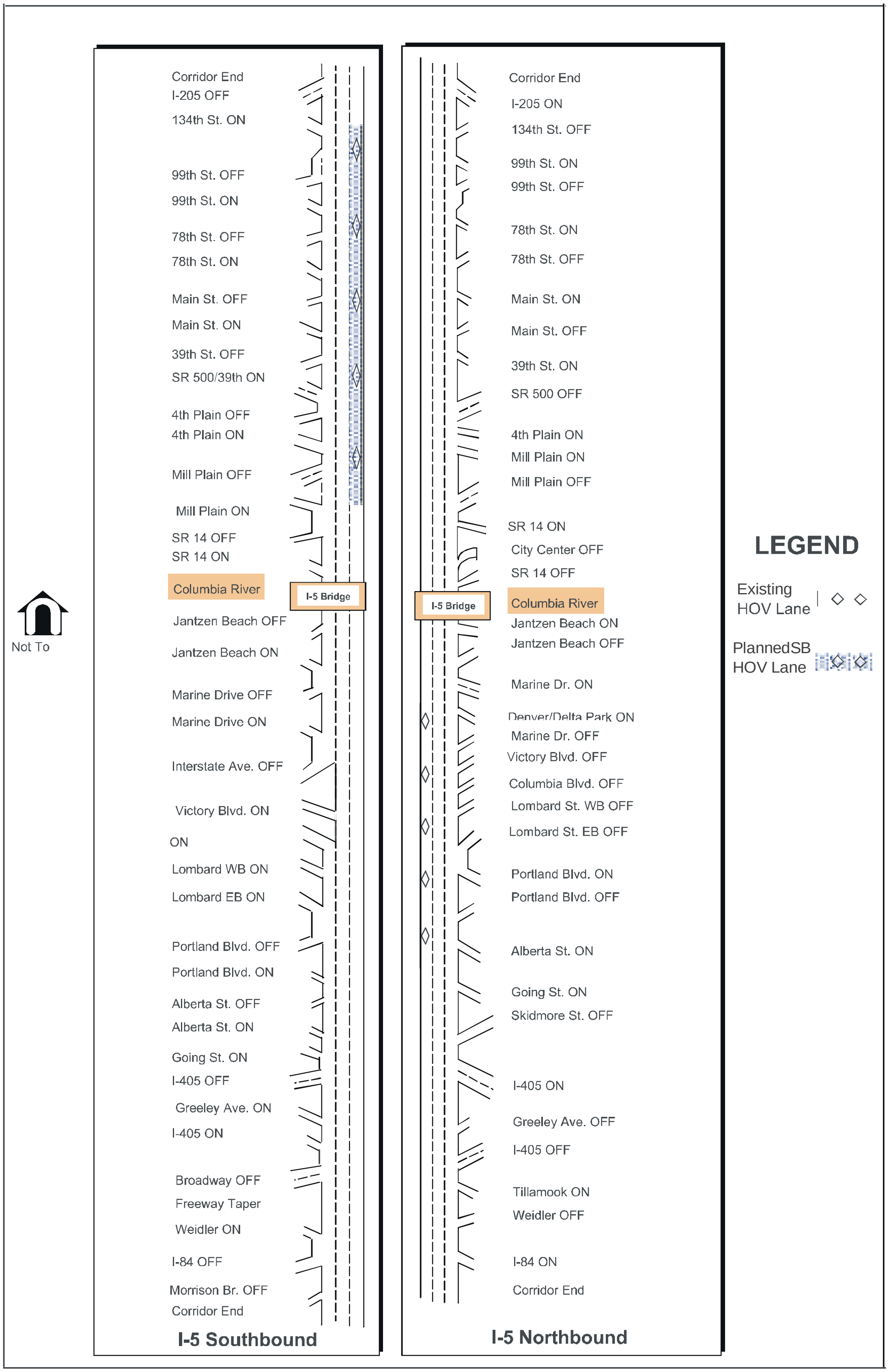


Figure 5. HOV Alternative 3 – Full Corridor Option A

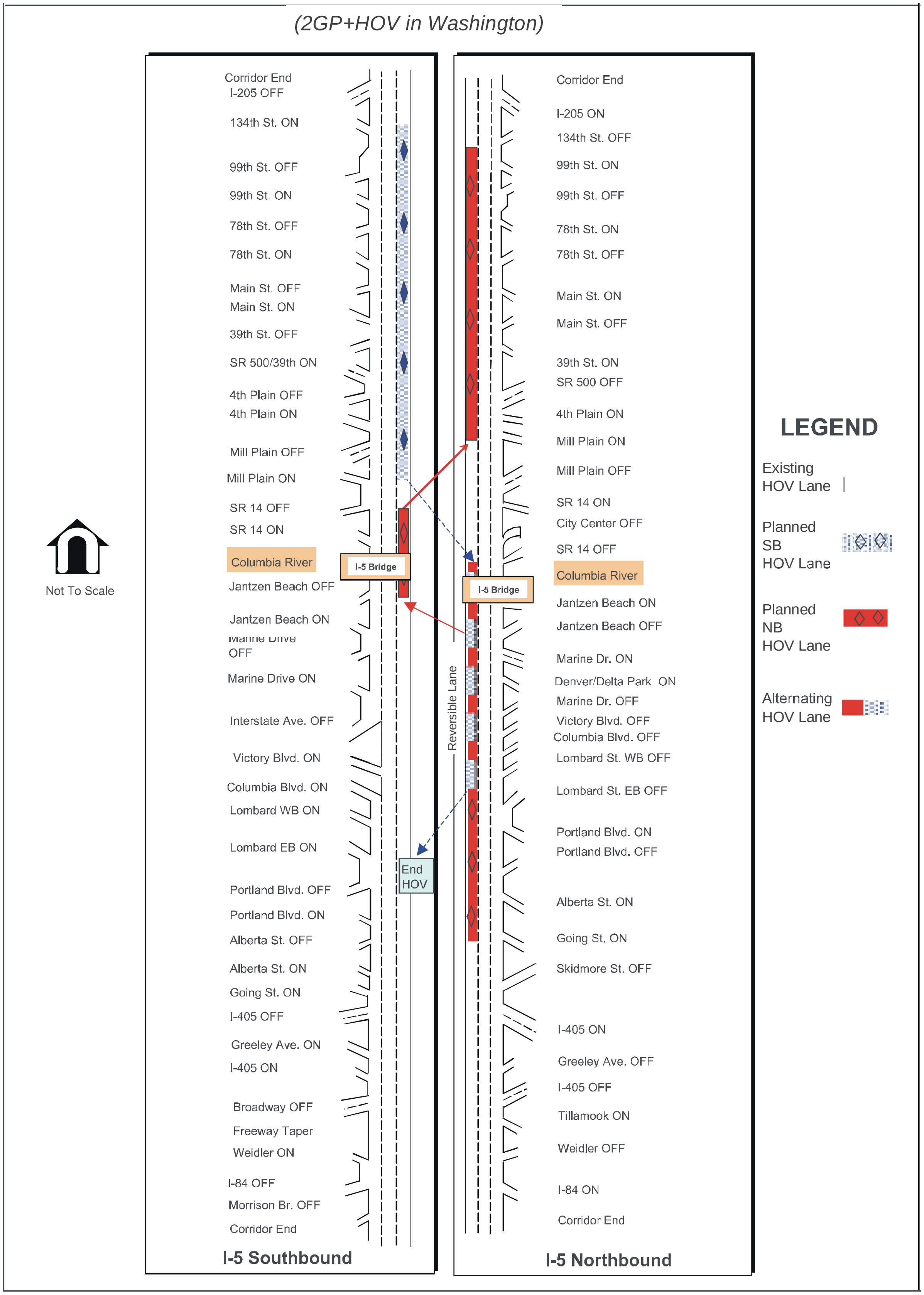


Figure 6. HOV Alternative 4 – Full Corridor Option B

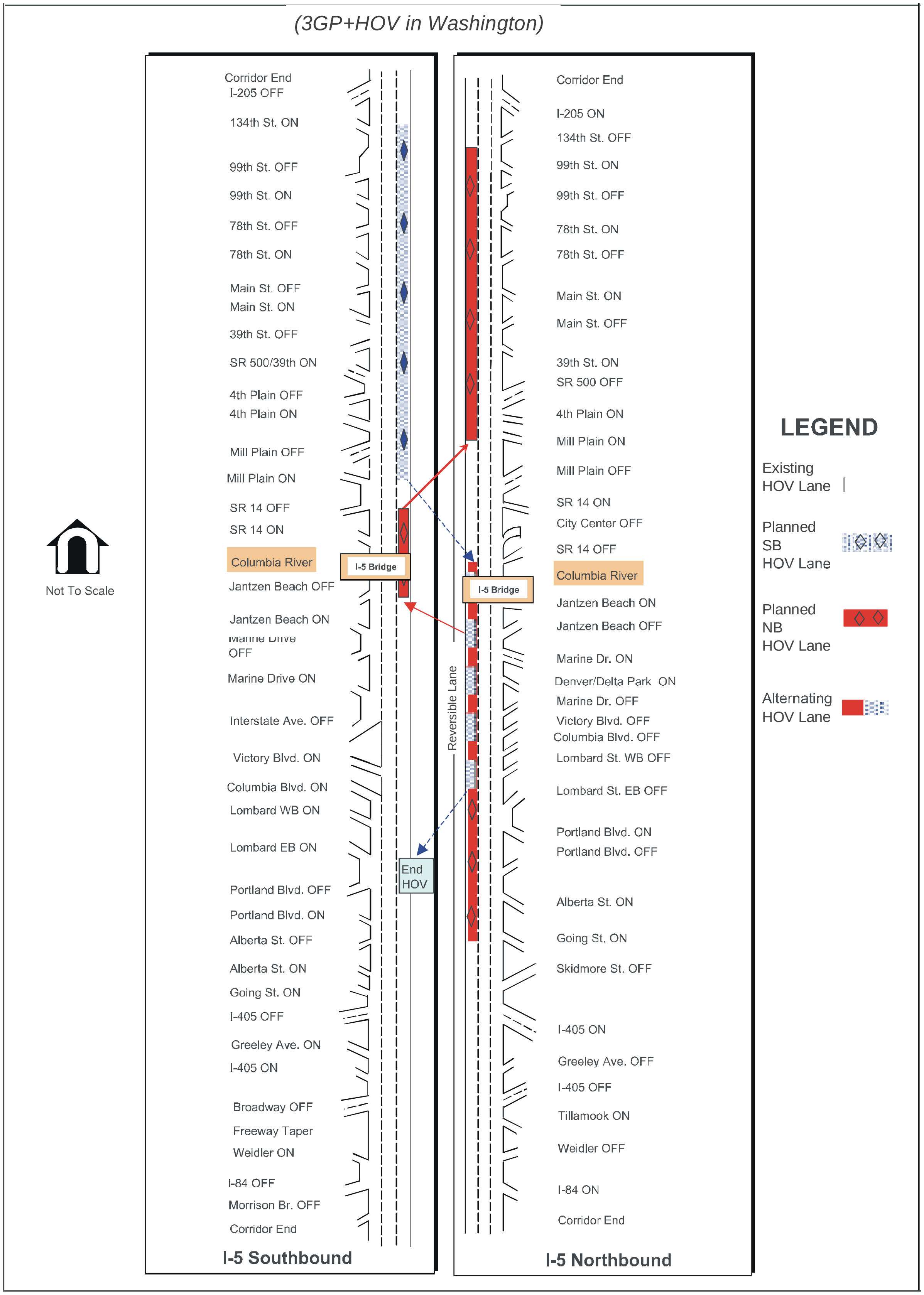


Figure 7. HOV Alternative 5 – Queue Bypass #2a

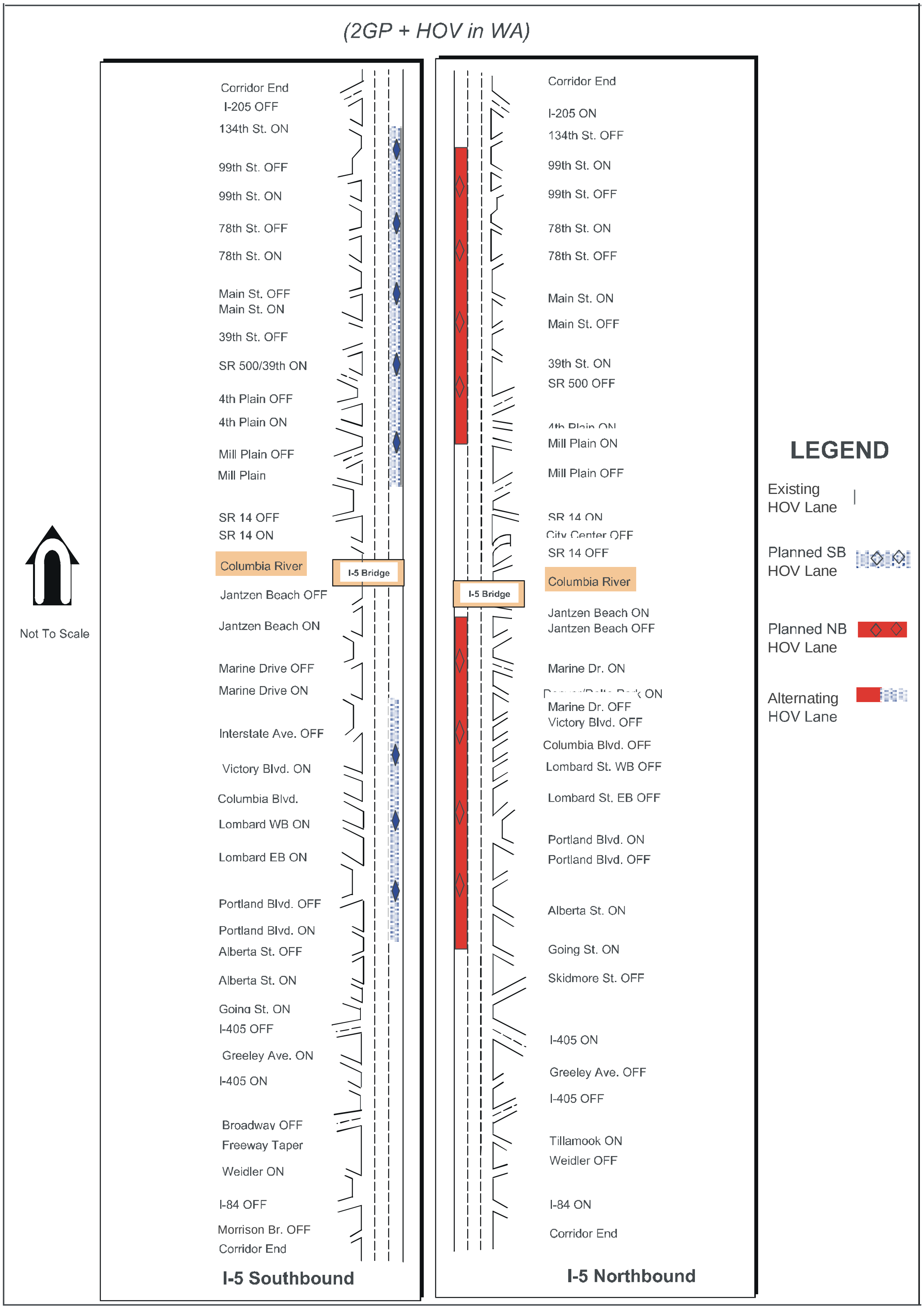


Figure 8. HOV Alternative 6 – Queue Bypass #2b

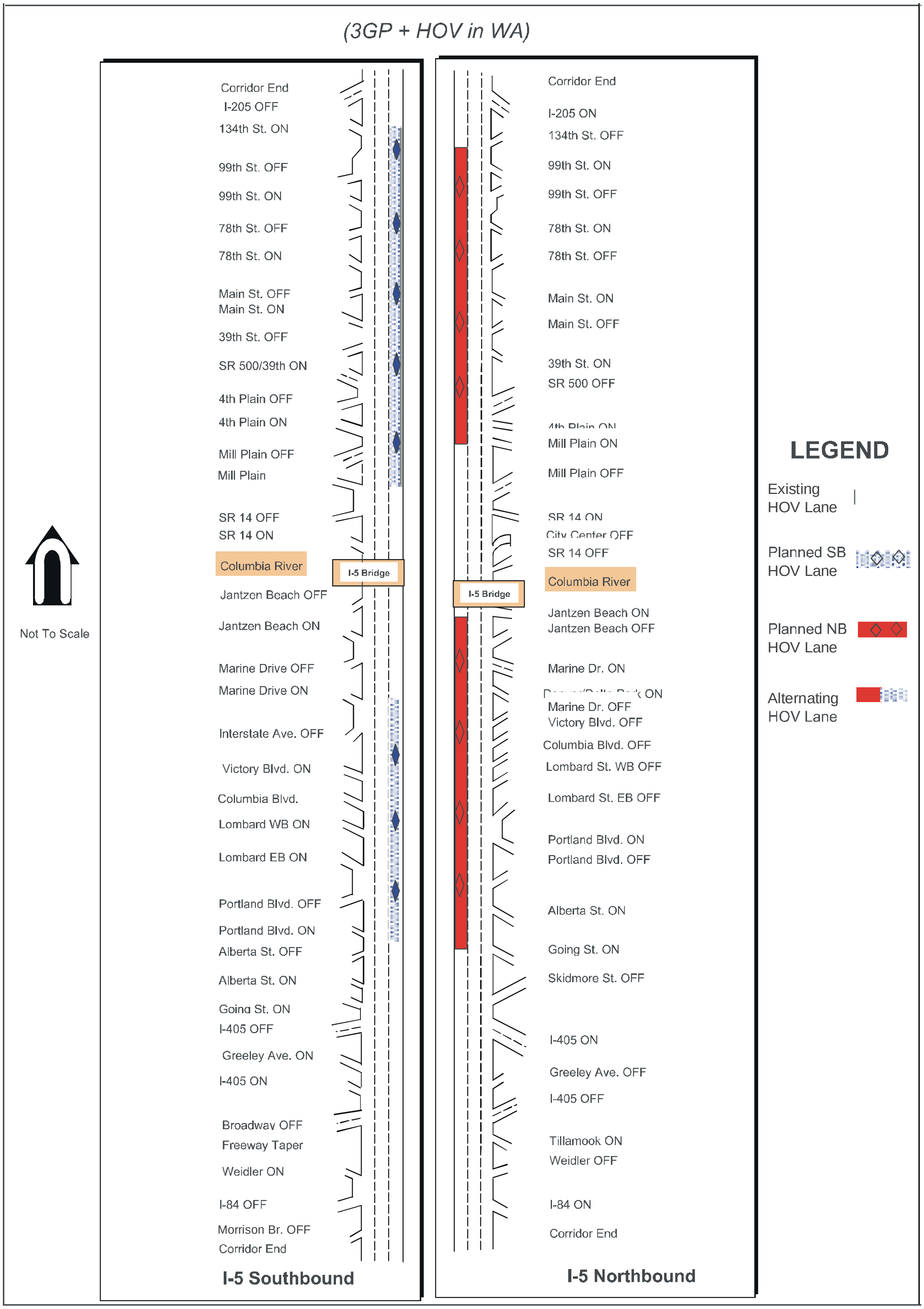


Figure 9. HOV Alternative 7 – Delta Park Only

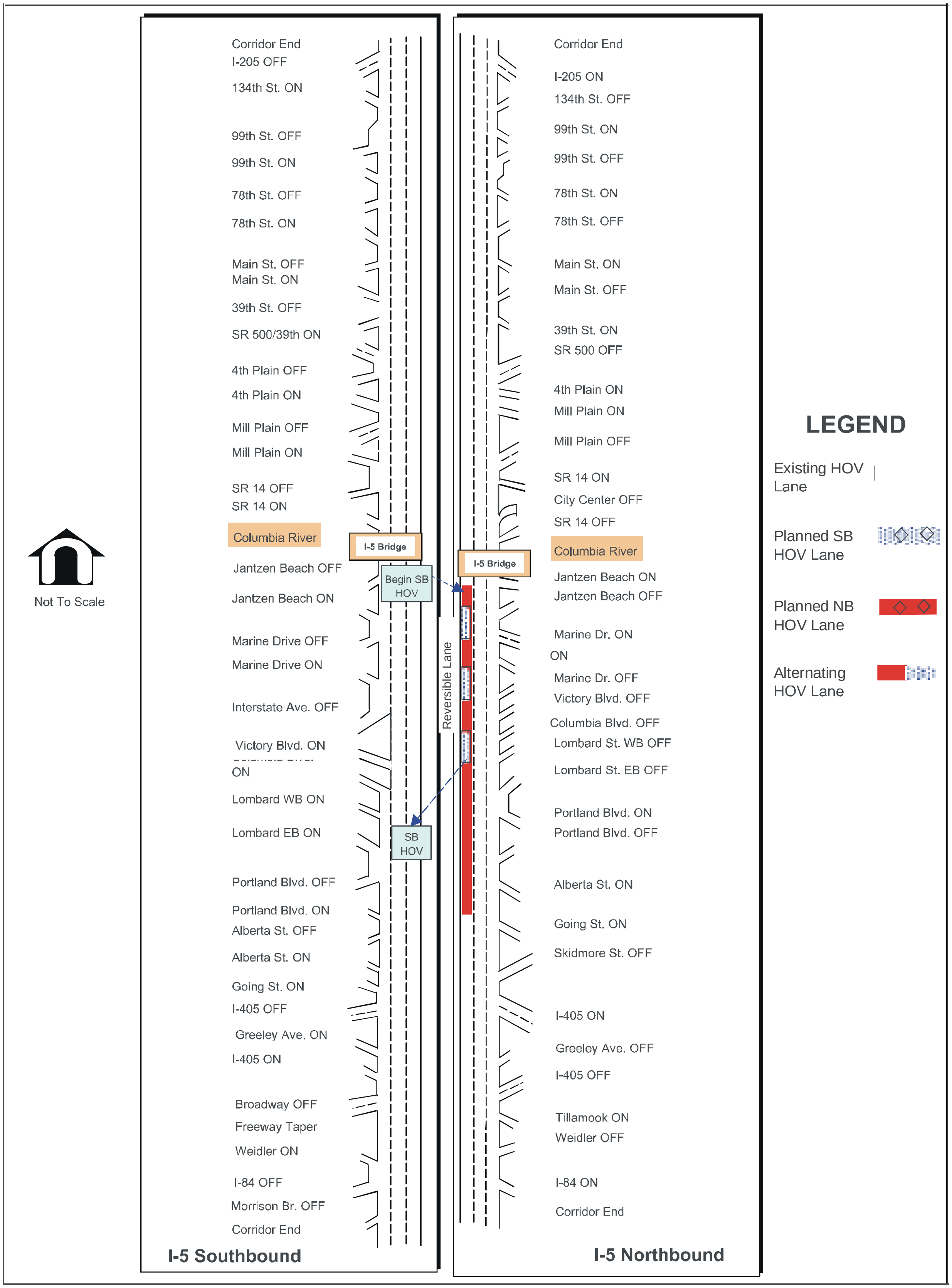
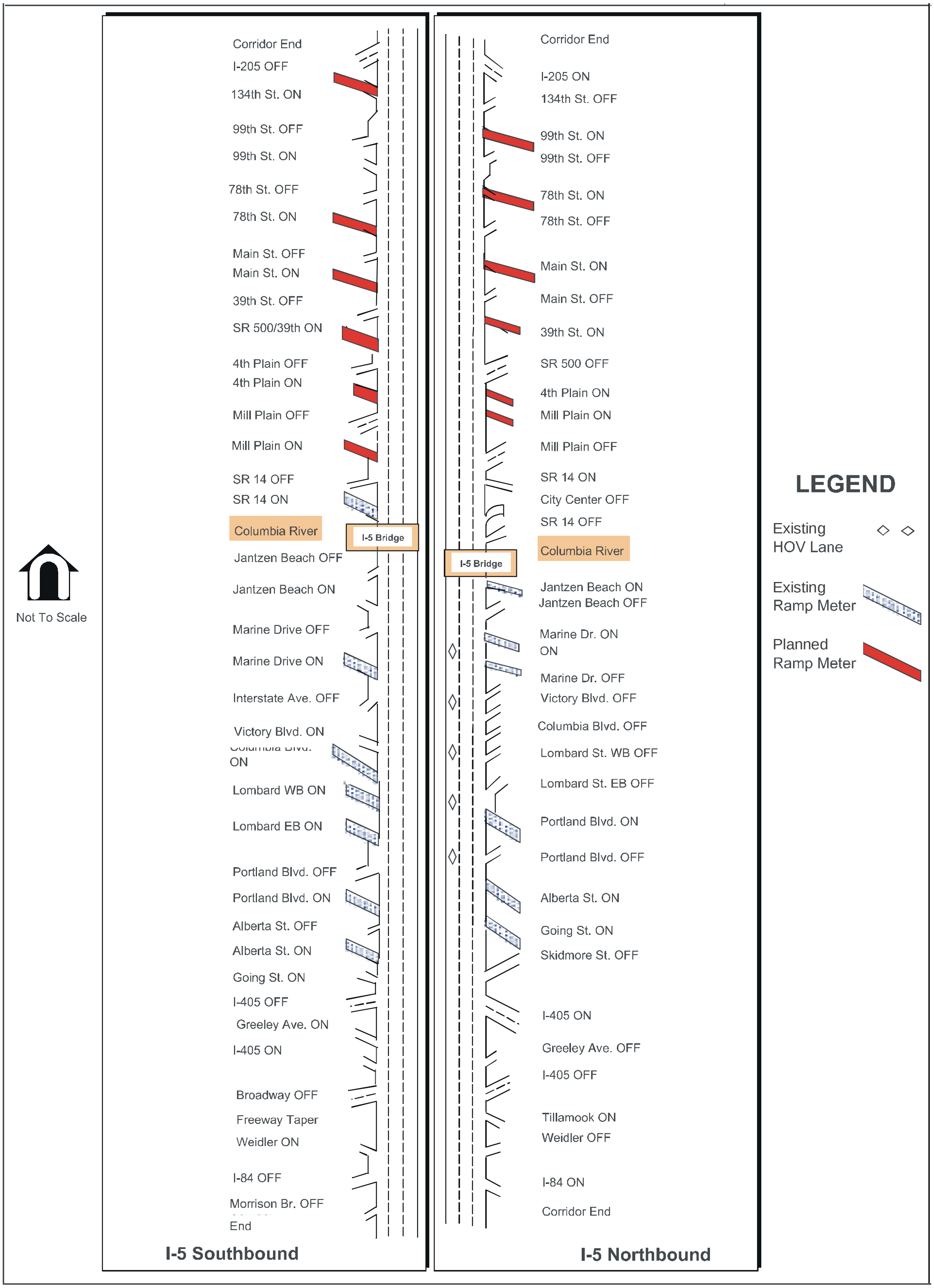


Figure 10. HOV Alternative 8 – TSM Alternative



RISK ASSESSMENT

Representatives from RTC, ODOT, WSDOT, and the consultant team drove the corridor to observe and discuss potential risk elements in the corridor. After this tour, the consultant team conducted a risk assessment which was presented to and discussed by the TAC.

This risk assessment was intended to identify potential implementation problems. Solutions were developed through the analysis and through the Physical Issues resolution process. Risk in this assessment was defined as providing a design that does not meet standards, potential to adversely affect traffic operations, increase accident rates, or create or exacerbate weaving or queuing problems on the Interstate 5 mainline.

The categories of risk are as follows:

- **No Risk**, where design of the alternatives meets or exceeds FHWA/AASHTO, ODOT, or WSDOT design standards. An example would be the widening of I-5 from Main Street to 99th Street, as designed by WSDOT, which would have 10- to 12-foot shoulders and 12-foot lane widths.
- **Low Risk**, where the facility's design is within approximately 10 percent of design standards, or where case studies exist in Oregon or Washington with similar design features. An example would be cases where lane widths are 11 feet in a 50 mph or less speed zone.
- **Medium Risk**, where the geometrics are substandard but measures would be considered to minimize risk. Examples would include restriping existing sections to add lanes but reduce shoulder widths to less than standard. Shoulder widths, however, would be similar to existing case studies elsewhere in Oregon or Washington.
- **High Risk**, where geometrics are currently substandard and the alternative would result in a facility that is even more substandard, and the potential for traffic operational or accident problems would be significantly increased. An example would be where a gap in a median dividing two directions of traffic is created by a design feature (loss of positive separation). The risk assessment field tour notes are attached.

The risk assessment is as follows:

Oregon

The risk assessment was conducted for this section based on a reversible lane design concept which would place the movable barrier between the left and center northbound lanes when the southbound HOV lane was operating and against the existing median barrier when the southbound HOV lane was not in operation.

Northbound: I-5 through Delta Park is approximately 35 feet between the inside and outside barriers. A movable barrier that would allow southbound contra-flow operation would utilize approximately 2-3 feet of this width, resulting in lane widths of 10-11 feet. If a reversible lane is operating, the width should be a minimum of 11 feet to accommodate C-TRAN buses, and the outside northbound lane should also be 11 feet wide to accommodate trucks. The center lane would be 10-11 feet wide.

The risk is determined to be medium. There are significant geometric issues; however, there are case studies of such conditions, including the Marquam Bridge prior to reconstruction, and I-5 and I-405 in the Seattle area when HOV lanes were first implemented. A potential risk is receiving concurrence from FHWA for design variances. An aggressive incident management program (beyond what ODOT has already implemented) would further reduce risk.

Southbound: A previous study by the consultant team indicated that restriping through Delta Park to accommodate three lanes southbound carried with it a high level of risk and was determined to be impractical. This risk is associated with exacerbating a currently substandard merge section with a high amount of truck traffic and with ramp-to-mainline speed differentials much greater than 10 mph. It is recommended that this option not be considered further.

Interstate Bridge

The risk assessment for the Interstate Bridge section was conducted based on a design concept which consisted of a reversible lane in each direction provided by a movable barrier. When in operation northbound, the movable barrier would be placed between the southbound left and center lanes between approximately Jantzen Beach exit and the Evergreen Boulevard overpass in Washington and would allow northbound HOV traffic to use the lane during the PM peak period. Similarly, when in operation southbound, the movable barrier would be placed between the northbound left and center lanes between approximately Jantzen Beach exit and the Evergreen Boulevard overpass in Washington and would allow southbound HOV traffic to use the lane during the AM peak period. When not in operation, the movable barrier would be placed against the left-hand barrier on the bridge. A gap would be designed in the barrier to allow the lift-span to be opened.

There are three areas that present risk:

- The ability of the lift span to lift the weight of a movable barrier
- Providing positive separation between opposing directions of traffic in a reversible lane scenario
- Providing adequate lane widths to accommodate reversible lanes.

The northbound structure is slightly over 36 feet wide between barriers and the southbound bridge is approximately 39 feet wide.

The 36-foot section provides a low-to-medium risk level. The lane widths with a movable barrier would be 10.5 feet (when not in operation, the movable barrier can be placed immediately adjacent to the side barrier, leaving approximately 34 feet for travel lanes). Risk is reduced as there are case studies (see above) with traffic under similar conditions and with possible replacement of the existing barrier with something narrower which would allow for wider lanes.

The southbound bridge presents a more desirable situation and should be able to provide 12-foot lanes, lessening risk.

The northbound lift span mechanism was recently retrofitted and there is speculation, based on conversations between ODOT and the consultant team, that the lift span may be able to accommodate some barrier weight (but perhaps not the entire weight of a barrier on the 280-foot lift span). The southbound span would require retrofitting to be able to lift the weight of a barrier.

The need to provide positive separation carries with it a proportionate level of risk. Positive (continuous barrier) separation carries low or no risk, while having an opening across the lift span increases the risk.

Washington

The risk assessment was conducted in Washington with two design options under consideration:

- Two general purpose lanes plus an HOV lane in each direction, which essentially would convert the existing left lane to HOV between the Interstate Bridge and SR 500. North of SR 500, where the widening project in underway, the left lane of the widened three-lane (per direction) section would be designated as the HOV lane.
- Three general purpose lanes plus an HOV lane in each direction. This would involve restriping the section from the Interstate Bridge to SR 500 to accommodate four travel lanes (three general purpose plus HOV) within the existing pavement, resulting in narrower left-hand and right-hand shoulders. North of SR 500, the widened section would be striped to accommodate three general purpose lanes plus an HOV lane in each direction.

With a restriping option for the existing section between the bridge and Main Street to provide three general purpose plus and HOV lane in each direction, the risk has been determined to be low if the left (inside) shoulder is no more than 4 feet wide (or is wide enough to accommodate vehicles stopping on the shoulder). The narrow shoulder would be consistent with approved treatments in the Puget Sound area on I-5 and I-405 and on the Banfield Freeway. In these cases, the inside shoulder is 3-4 feet wide. In the Puget Sound region, FHWA directed WSDOT to either stripe a shoulder narrow enough to prohibit vehicles from stopping on the shoulder or wide enough for the vehicles to stop completely out of the traffic lane. WSDOT implemented the former with FHWA approval. It is recommended that WSDOT stripe for a maximum 4-foot inside shoulder to be consistent with these case studies.

This striping should allow for a 6-foot outside shoulder. This is not wide enough to accommodate a stopped vehicle completely out of the traffic lane. Risk could be reduced by providing incident/enforcement areas where the shoulders are wide enough to store vehicles or by widening the outside shoulder in the future. There are several locations where the shoulder is wide enough to store vehicles under this scenario.

The risk assessment also applies to the soon-to-be-widened section between Main Street and 99th Street. Risk is lowest (no risk) if WSDOT implements the designed section (2 general purpose plus HOV); risk is low if WSDOT stripes for standard merge sections instead of auxiliary lanes in a 3 GP + HOV scenario; risk is somewhat higher for a 3 GP + HOV + auxiliary lane scenario.

Southbound, more detailed analysis is needed for the section between Main Street and Mill Plain, where SR 500 joins I-5. Weaving and merging traffic are risk issues in this section. If ramp metering is implemented for the SR 500 on-ramp, risk of traffic diversion could be minimized by metering adjacent I-5 on-ramps at the same time.

The Risk Assessment provided an encapsulation of the physical issues which needed resolution. These issues and potential resolutions are discussed below.

Delta Park Area

The physical issues are as follows:

- The northbound bridge structures through Delta Park (Slough bridges) are narrow with no shoulders

- There are twin bridge structures. The connection of two bridge structures and use of movable barrier may cause traffic concerns and potentially faster deterioration of bridge joints.
- The ability to achieve positive separation of opposing traffic and maintain adequate lane width
- Incident Management in reversible lane
- Southbound merging of HOV traffic into general purpose lanes

The existing bridges are two parallel multi-span structures, length 5 x 104 feet = 520 feet, width each 38 feet from centerline to curb line. A concrete barrier is placed directly above the longitudinal deck joint.

Given the narrow section in this area one possible option is to remove the fixed barrier and replace it with a movable barrier for a reversible HOV lane. The reversible lane would allow operation of an HOV lane through this section. However, there could be significant operational concerns with requiring a left-hand merge. There is also a potential problem resulting from differential deflections at the bridge joints that would need to be addressed further if this option was advanced.

Washington

The physical issues in Washington mainly result from the lane configurations being considered. These issues are:

- 2GP lane + HOV lane versus 3GP lanes + HOV lane
- Median and outside shoulder widths in each configuration

Interstate Bridge

The Interstate Bridge presents the most significant physical issues to resolve. These are:

- Use of movable barrier on the bridge and the lift span
- Width of traveled way in each direction and lane widths
- Ability of lift span to lift weight of additional barrier
- Need for positive separation between opposing directions of traffic
- Merge and diverge of reversible lane(s) at each end of bridge

The total bridge length is 3,534 feet, consisting of a 278-foot vertical lift span, 2,940 feet of fixed through truss spans, and 316 feet of girder type spans. The bridge width is approximately 36-39 feet between curbs on each bridge structure with the southbound structure being approximately two feet wider than the northbound structure.

Placement of movable barriers on the lift spans was considered but eliminated for several reasons, including:

1. The lift span cannot lift the weight of a new barrier in the lift bridge. These barriers get their stability from their mass and width of footing. The weight would be about 280 feet x 450 plf = 126,000 lbs per bridge. According to Frank Nelson, ODOT Bridge Engineer, a maximum added load of only 80,000 lbs would be acceptable to ODOT.
2. The barrier would need to be disconnected to allow for bridge lifts.
3. There is no known existing currently operating installation of a movable barrier on a lift span. To develop a properly functioning system with acceptable construction impacts might require replacement of the lift span. This was considered beyond the scope of this study, since this HOV arrangement represents an interim solution.

Placement of fixed barriers on each bridge were investigated as an alternative. These barriers would be fabricated steel and bolted to the bridge deck, thus staying within the weight limitation on the lift span. On the fixed spans, these barriers could be concrete or steel. The lanes separated by these barriers would function as contra-flow HOV lanes or as express lanes.

Another option for traffic separation for reversible lanes is use of removable pylons. While this was originally eliminated during the early stages of the study (due to lack of positive traffic separation), the Peer Review Panel recommended re-examining pylons as they are in use on other reversible lanes, can be lifted by the lift span, and do not require the loss of roadway width that a concrete barrier would present.

PHYSICAL ISSUES RESOLUTION

During the course of this study, several design and operational concepts were considered for the reversible lane options across the Interstate Bridge and through Delta Park. These are listed below with a description of how they were revised during the study:

- Delta Park: two options for movable barrier were considered. One option placed a movable barrier in traffic for the southbound HOV operations in the AM peak period, and would be moved against the current barrier for the rest of the day. This would have resulted in an 11-foot wide HOV lane in the AM peak period that would have no shoulders and barriers on each side. Given that there is currently no shoulder through Delta Park and that this would further reduce lane width, this design was found to be unworkable. A second option replaced the current median barrier with a movable barrier. The barrier would be moved depending on time-of-day and the HOV lane would have a striped separation from general purpose traffic in the direction of travel instead of a barrier separation. While this option provided a wider lane section, the option results in left-hand merges and lack of safety shoulders. The second option was analyzed further in Phase II of this study.
- Interstate Bridge: the original concept of a movable barrier across the bridge was dismissed due to impacts on lift-bridge operations and the impracticality of designing and operating a movable barrier on the lift span. It was replaced with a concept of movable barriers or entry gates at each end of the bridge to allow HOV lane access and egress, and permanent barriers on the Interstate Bridge. This concept was eliminated due to the lane width reduction and obstacles created by the permanent barrier and replaced with consideration of movable pylons separating opposing directions of traffic. Concerns about lack of physical and crashworthy separation of opposing traffic directions led to the elimination of this and all

consideration of reversible lanes on the Interstate Bridge. A more detailed analysis of the reversible lane concepts was included in Phase II of the study.

FINDINGS AND CONCLUSIONS ON TRAFFIC SEPARATION TREATMENT ON INTERSTATE BRIDGE

The consultant team conducted an assessment of the barrier alternatives. The use of a movable barrier was ruled out as being too impractical to operate, too heavy for the lift span to raise, and difficult to design. A concept was developed which would install a permanent, crashworthy barrier in each direction along the entire length of the bridge, with a gap to allow for lift operations, between the left and center lanes to allow for reversible, contra-flow HOV lane operations. This assessment is based on field investigations, traffic operational analysis, and case studies of similar treatments.

The northbound bridge structure is approximately 36 feet barrier-to-barrier, while the southbound structure is approximately 39 feet wide. A fixed barrier would be approximately 2 feet wide at the base (but perhaps could be designed slightly narrower) and could be designed so that it is 1-foot wide at the top. Field observations elsewhere indicate that shy distance (the motorists' perceived safety distance to prevent colliding with the barrier) is about 2 feet, which effectively narrows adjacent lane(s) by 2 feet. In analyzing the concept of a fixed barrier on the bridge, a conceptual design was developed for the barrier's beginning and ending points in each direction.

In the northbound direction, the barrier would begin near the Jantzen Beach interchange, where the left shoulder is approximately 6-8 feet wide. A small gore and diverge point would separate the left and center lanes and the barrier would begin near that point. The barrier would end on the north side of the bridge, at approximately the City Center exit, to prohibit vehicles in the left lane from making a sudden weave to use that exit. Resultant lane widths would be approximately 11 feet with no shoulder.

In the southbound direction, the barrier would begin at approximately the SR 14 off ramp, to prohibit vehicles entering southbound I-5 from SR 14/downtown Vancouver from making a sudden weave to enter the lane. A small gore and diverge point would separate the left and center lanes. Resultant lane widths would be approximately 13 feet for the left lane and 12 feet for the other two lanes with no shoulders.

Impacts of Reversible Lane on Non-Peak Traffic

In assessing the impact on traffic operations of taking a lane in the non-peak direction for a contra-flow HOV lane, a review of peak period traffic counts in the non-peak direction was undertaken as part of the Interstate Bridge Painting Traffic Management Plan development. With a two-lane concept, it is estimated that the non-peak capacity is approximately 3600 vehicles per hour. In the AM peak period (6-9 AM), there are no hours where the volume is at or above this level. However, during the PM peak period (2-8 PM), there are 2-3 hours where counts met or exceeded this level. Exceedances were on the order of 5-8 percent (200-300 vehicles) per hour.

In reviewing Year 2020 PM peak-hour volumes in the southbound (non-peak) direction, volumes approached 5,000 vehicles per hour. This would significantly exceed the two-lane capacity. In fact, these volumes are similar to what is currently being experienced northbound.

From an operational perspective, further analysis is needed to determine actual impacts of a permanent contra-flow traffic operation. This analysis would need to include:

- FREQ modeling of the non-peak, two-lane direction (current and 2020)
- Comparison of corridor travel times for all vehicles (both directions) under a normal flow versus the contra-flow, non-peak lane conversion scenario

Impacts are defined on a corridor-wide, two directional basis considering level-of-service, travel time, and delay. These are similar to the goals of the HOV Lane Pilot Project, where one goal was to reduce travel time for HOV lane users and not have a net negative impact on travel time for all users. Major impacts are defined as a lowered level of service (one class or more, such as from LOS E to LOS F) in one direction, while minor impacts may increase delay but not reduce level-of-service by one class or more. On a short-term basis, such a configuration may be implementable without significant impacts. However, in the longer term, this configuration may either need to be removed (and converted back to three lanes in each direction during the PM peak) or the bridge replaced with a four-lane per direction structure.

The impact on traffic operations in the AM peak is less pronounced. It is likely that in the short term (next 10 years) taking a northbound lane to convert to a southbound HOV lane could be accommodated without significant level-of-service impacts to the non-peak (northbound) direction. In the short-term, the AM peak period volumes southbound are lower than the northbound PM peak period volumes; if adding a fourth lane southbound resulted in significantly lower general purpose lane congestion, the attractiveness of the HOV lane could be reduced. A fourth (HOV) lane southbound on the bridge should only be accompanied by scenarios which provide for three lanes (two GP plus HOV) through Delta Park.

Geometrics and Safety

There are several examples, both locally and nationally, of permanent barrier separation between lanes and instances where lane widths are reduced during construction. The difficulty is a permanent operation where the lane widths are reduced to 10-11 feet. The impact on freight and buses is more pronounced, as they will likely travel through the area much more slowly than passenger vehicles to avoid collisions. The left lane northbound would be approximately 11 feet wide with no shoulders for a distance of approximately ½ mile.

Southbound, with a wider structure, the lane widths could be near standard, and, in fact, the reversible lane could be as wide as 13 feet to allow for a shoulder/shy distance. This would lessen the impact on trucks and buses using that lane (during non-HOV operations). The lane would still have no shoulders and a 13-foot width for approximately ½ mile. The northbound direction in Washington could be restriped as far north as either SR 500 or Main Street to accommodate a fourth lane, which would allow the HOV lane on the bridge to enter concurrent flow traffic as an add-lane rather than a merge. Further consideration should be given as to whether trucks should be allowed in the left lane under the permanent barrier scenario.

Case Studies

There are no known case studies of a reversible lane being operated on a drawbridge with a barrier installation. Further research is needed to locate examples that are similar to the Interstate Bridge situation.

A reversible, barrier separated HOV lane was implemented on the Katy Freeway in Houston with sections that narrowed to 11 feet (at bridge columns) with no adverse impact on safety. However, these were short (less than 300 feet) sections. A reversible, movable barrier HOV lane is in place on I-30 in Dallas, Texas. The barrier is placed between two lanes which are each 13 feet wide, resulting in 12-foot travel lanes. There is no inside lateral clearance but there is an 8-10 foot wide shoulder on the outside. On I-495 in New Jersey, on the approach to the Lincoln Tunnel, an exclusive, contra-flow bus lane is provided (separated by pylons from the opposing traffic direction) with a 10.9 foot lane width. Speeds are reduced to 35 mph and buses must travel with their headlights on. A bus-only lane was operated in the late 1970's to 1980's on the Golden Gate Bridge by taking two non-peak lanes. Lane widths were narrowed to approximately 11 feet. The project was removed when traffic grew above thresholds in the non-peak direction.

Incident Management

An enhanced incident management program would likely be needed to quickly respond to and clear vehicles to allow traffic to operate. With a permanent barrier, all vehicles behind a stopped vehicle are trapped, and would not be able to exit the lane without removing the barrier or the stalled vehicle. An incident management program would likely consist of stationing a tow truck at each end of the bridge, which would back into the reversible lane to clear the stopped vehicle(s).

Conclusions

While operationally a reversible lane on the northbound structure could be implemented for southbound AM peak HOV use, the resultant lane widths are substandard and the presence of a fixed object between lanes of traffic increases agency risk. Additionally, the southbound direction has a lane imbalance and less congestion than in the PM peak. If the resulting southbound congestion were low enough, it may reduce the attractiveness of a southbound HOV lane.

For the PM peak, the addition of a contra-flow HOV lane on the southbound structure would have minor impacts on southbound traffic in the short term, but more pronounced impacts in the longer term. A more detailed analysis of the I-5 HOV bridge treatment was conducted during Phase II of the study.

During Phase I, a Peer Review Panel was convened to review and comment on the HOV alternatives and to respond to a series of questions regarding HOV treatments applicable to the I-5 corridor (see the Peer Review summary later in this report).

The Peer Review Panel responded to various reversible lane treatments on the Interstate Bridge. They concurred that movable and fixed barrier treatments on the bridge were impractical and problematic due to impacts on lane widths, traffic operations, and potentially safety. They recommended consideration of movable pylons separating opposing traffic directions on the Interstate Bridge, similar to treatments elsewhere (including the Golden Gate Bridge in San Francisco).

The Peer Review Panel also mentioned that they are familiar with reversible HOV lane operations that have substandard shoulder widths and concluded that in most instances there have not been any long-term accident problems which were encountered.

RECOMMENDED PROMISING ALTERNATIVES FOR FURTHER ANALYSIS

Screening to Promising Alternatives

Generally, defining the promising HOV alternatives consisted of:

- Designating the number of general purpose lanes per direction

- Identifying northbound and southbound configurations, including beginning and endpoints (which may be different by direction)
- Designating whether the HOV lane is reversible (barrier-separated, contra-flow) or concurrent flow with continuous access
- Identifying configurations specific to Oregon, Washington, or the Interstate Bridge

In order to narrow the list of alternatives, minimum and maximum operating thresholds were set by the technical team:

- A minimum of two general purpose lanes must be maintained in each direction (minimum of three general purpose lanes in each direction between SR 500 and the Interstate Bridge)
- The maximum number of lanes per direction (GP + HOV) is four
- The length of movable barrier (reversible lane) must be no longer than what could be moved (reversed) in one hour.

Of the eight alternatives under consideration, four alternatives included a decision on the Washington side as to whether the section should be 2GP+HOV or 3GP+HOV, with the same operating characteristics and endpoints. For the next stage of this study, it was recommended that an analysis be carried out which determined which of these two sections was optimum for the corridor.

The recommended alternatives fall into the following categories:

- Bi-State HOV with Bridge HOV
- Bi-State HOV with no Bridge HOV
- Queue Bypass HOV (Oregon-only northbound, Washington-only southbound) with no Bridge HOV
- Transportation Systems Management HOV (current northbound HOV lane plus ramp meter HOV bypasses).

Alternative #1, the “No Additional HOV” alternative, was the baseline for comparison and was retained throughout this process.

Alternative #8 was considered the TSM alternative. With the 2020 scenario, the on-ramp volumes were extremely high, and taking a lane for an HOV bypass had net negative benefits. Additionally, there were no studies that the TAC or the consultant team were aware of that indicated having HOV bypasses of ramp meters led to a mode shift (rather, a regional HOV lane tends to affect mode shift). ODOT has been removing HOV ramp meter bypasses in favor of converting them to general purpose, because of the queue lengths on the ramps currently, and this will likely continue in the future. It was recommended that Alternative #8 be dropped from further consideration.

The remainder of the alternatives could be grouped into the following HOV “strategies”:

- Oregon-only; queue bypass: no HOV lane(s) on the Interstate Bridge (Alternatives 1 and 7)
- Oregon-Washington; queue bypass: HOV lanes are implemented on I-5 leading to the Interstate Bridge in each direction between Going Street and 134th Street, and possibly continued after the bridge, but not on the Interstate Bridge (Alternatives 1-2 or 5-6)

- Oregon-Washington; full corridor: HOV lanes would be implemented on the I-5 corridor from 134th Street to Going Street, including the Interstate Bridge (Alternatives 3 and 4)

There were still issues to be resolved under these strategies, which included:

- How HOV is implemented in Oregon (reversible lane with movable barrier, southbound widening in Delta Park)
- Whether or not HOV is implemented on the Interstate Bridge
- Determine if queue bypass HOV lanes should be continued again after the Interstate Bridge
- The number and type of lanes in Washington (2 GP+HOV, 3GP+HOV)

Recommendation

The following three HOV strategies were recommended to be carried into Phase II for more detail demand and operational analysis:

- **Full Corridor Option**: HOV lanes from 134th Street in Washington to approximately Lombard Street (southbound) or Going Street (northbound) in Oregon including a reversible HOV lane across the Interstate Bridge and a movable barrier through Delta Park
- **Delta Park Option**: A reversible HOV lane only in the portion of the corridor where the existing northbound HOV lane is located (southbound the HOV lane would end near Lombard Street)
- **Queue Bypass Option**: The addition of an AM peak southbound HOV lane in Washington similar to the current PM northbound HOV lane in Oregon. Further analysis will include determining if the HOV lane should be re-started on the other side of the Interstate Bridge.

HOV EVALUATION AND RESULTS

Phase II of the I-5 HOV Operational Study analyzed the HOV strategies using the 20-year modeling analysis described earlier in this report. More detailed analysis, design work, public involvement, and a second Peer Review Panel were used to assist the Technical Advisory Committee in selecting a preferred HOV Alternative.

Modeling and Analysis Methodologies

Representatives from Metro, RTC, and the consultant team met to discuss and agree on a modeling and post-processing analysis methodology for the I-5 HOV Operational Study. The following outlines the modeling and analysis methodology.

It is important to understand the model hierarchy used for this analysis. Each model used had specific purposes based on the analysis need. The model hierarchy is shown in **Table 1**.

Table 3. Model Hierarchy

Model	Source	Applications	Limitations
Regional: EMME/2	INRO	Regional transportation demand, diversion between I-205 and I-5, mode shifts with regional HOV facilities	The model is a demand model but is less sensitive to traffic operational issues such as queuing and weaving congestion.
FREQ	UC-Davis	I-5 corridor traffic operations (based on regional model demand), queues due to congestion, merging, weaving	Applicable for corridor-wide queuing and weaving analysis, but may not be sensitive to specific locational issues such as short segments of the I-5 corridor.
Charles River HOV	Charles River Associates, 1986	HOV mode shifts due to HOV treatments, based on FREQ and VISSIM speed output	Purely a demand projection model. It is not a traffic operations model.
VISSIM	PTV AG of Karlsruhe, Germany November 1999	Locational traffic operations for short segments of the corridor, weaving and queuing analysis, testing of lane configurations on I-5 segments	Uses HOV demand and FREQ model volumes as inputs. Does not estimate mode shift due to HOV facilities.

REGIONAL MODELING

The intent was to undertake analysis for this study that was consistent with the I-5 Trade Corridor Study. The 2020 modeling work to date on the "No New HOV" Baseline scenario was compared to the "New" Baseline for the I-5 Trade Corridor Study. The comparison of travel demand in the I-5 corridor showed about a 5 percent difference between two-hour PM peak direction vehicle volumes on I-5 at the current endpoint of the HOV lane. Differences in demand volumes in the corridor were considered minor; however, RTC implemented the following suggestions to maximize consistency between the two models:

- Comparison of I-205 demand
- Review of peaking factors
- Implementation of identical ramp meter volume delay functions

The 2020 PM peak one-hour and two-hour models indicated that demand volume greatly exceeds capacity in the I-5 north corridor and on both Columbia River crossings.

As a result of this finding, the regional model was run, with ramp metering rates turned on, for 7-9 AM, 4-6 PM, and 6-7 PM peak periods and the 2-3 PM midday period. The analysis year was 2020. RTC used separate general purpose and HOV skims to run mode choice, and used a multiclass vehicle assignment.

To resolve the Washington laneage options (2 GP lanes plus HOV lane versus three GP lanes plus HOV lane), the regional model was run for both scenarios. The section of I-5 between the Interstate Bridge and Main Street, under the 2 GP plus HOV scenario, was considered a lane conversion under WSDOT HOV policy and therefore was also analyzed pursuant to WSDOT's lane conversion policies. Later, the TAC recommended adopting a minimum of three general purpose lanes in this section.

RTC developed a Year 2003 regional model run (AM peak period only) to estimate opening year conditions at the completion of the current I-5 widening project in Washington.

POST PROCESSING

The FREQ model was used to assess traffic operations and assist in design work. For the I-5 Trade Corridor Study, two 2020 NO NEW HOV FREQ models were developed: a four-hour northbound PM peak period model (2-6 PM) and a three-hour southbound AM peak period model (6-9 AM). For the I-5 HOV Operational Study, a review of the peak period demand versus the operational capacity of the I-5 corridor indicated that the 2020 four-hour peak period would likely spread to a five-hour PM peak period, thus, the PM FREQ model was expanded by one hour to create a five-hour PM peak period model. The FREQ model was run on each alternative to generate statistics which were used to compare the alternatives.

The Charles River Associates' HOV model was used to determine changes in HOV demand by alternative. Input from the regional model and the FREQ model was used to assist in the HOV demand modeling.

The VISSIM model was used to assess weaving impacts at up to five locations in the corridor and for highway simulations in the public involvement process. Different lane configurations between SR 500 and the Interstate Bridge were tested with VISSIM.

The Year 2003 regional model runs were input into the post-processing analysis to help understand opening year conditions.

APPLICATIONS

The regional travel model was used to establish corridor travel demand. In order to allow for a consistent review of the alternatives, the trip distribution and mode split applied to the No-New HOV alternative was used for travel demand for all HOV alternatives. The model is sensitive to transportation network changes, such as new Columbia River bridge capacity and HOV lanes. This sensitivity often results in bi-state changes in trip distribution and mode split that would result in not only analyzing the differences between HOV alternatives, but also regional changes in travel patterns that would have confused the evaluation process. While this may underestimate the mode shift into HOV's resulting from an HOV system, it "levels the playing field" by retaining the same travel demand for all alternatives.

The FREQ model adjusts the corridor travel demand by using calculated freeway and HOV capacity and a time-based trip analysis to determine how the corridor would actually operate. In essence, the model found that the demand greatly exceeded the corridor's capacity and physical capability of accommodating such a large amount of traffic. Thus, the model "spread" the peak by shifting traffic demand outside of the peak hour. Simply put, the queues were forecast to build up during the peak, and trips that entered the model study area would experience delays in reaching their destination to the point where they may end in a different peak hour than when they entered the system.

While the FREQ model allows an analysis of corridor-level traffic operations, it is not as sensitive to locational congestion levels. For example, the FREQ model did not forecast a queue through Delta Park southbound in 2020, due to the metering effect of the Interstate Bridge on southbound traffic (and also northbound in the PM peak). Engineering judgement determined that since there is a queue through Delta Park under current conditions, and that since traffic volumes are forecast to increase between now and 2020, there would continue to be a queue in 2020.

The VISSIM traffic simulation model was used to analyze short segments of I-5. This model indicated that there would indeed be a queue forecast through Delta Park in 2020 southbound in the AM peak period. It also determined that there would be some time savings for HOV users through Delta Park compared to general purpose traffic.

The Charles River HOV model was used to estimate HOV mode shift. For corridor-level HOV applications, the FREQ model output speeds and delays were used as input to determine impacts on HOV. For the Delta Park scenarios, the VISSIM speeds were used to analyze HOV instead of the FREQ speeds.

Evaluation Criteria and Methodology

Using Performance Goals developed for the ODOT HOV Pilot Project and using the WSDOT Northwest Region HOV System Policy as examples, a set of evaluation measures were established to evaluate the alternatives and provide a basis of comparison. As HOV lanes have the mission of increasing the person throughput in a corridor (or using person-carrying capability as the measure of effectiveness), the evaluation criteria relate to how well each alternative moves people along the I-5 corridor.

Evaluation measures include:

- Person throughput
- HOV lane utilization (at least 600 vehicles per hour in the HOV lane)
- HOV lane carries more people per hour than any adjacent general purpose lane
- Transit ridership
- Travel times for HOV and general purpose users
- Time savings for HOV users of at least five minutes overall and at least one minute per mile
- Public opinion regarding HOV
- Enforcement and incident management capabilities
- Traffic safety and operations

Bridge Options

Subsequent to the previous Peer Review, further review and meetings with RTC and the two DOTs resulted in continued safety concerns with the lack of physical traffic separation afforded by pylons. Design aspects were also of concern where the current fixed barrier would be permanently removed at the transition areas and replaced with pylons that would open and close the reversible lane (a gate option is unlikely due to the length of the transition area). It was decided that the pylon-only option be dropped. At this point, there were two options that appeared to be viable for the bridge:

- Movable barrier the entire length of the reversible lane, with a 270-foot gap on the lift span where movable pylons would be placed during contra-flow operations. The barrier would be moved against the inside bridge barrier, resulting in a loss of two feet from the current 36-37 foot travel surface, during other times of the day and the pylons would be removed
- Movable barrier the entire length of the reversible lane, including the lift span. When the HOV lane is closed, the barrier on the bridge segment would be towed off of the lift span and stored elsewhere (not on the lift span), and the remainder of the barrier would be stored against the inside bridge barrier. An agreement would be needed with the Army Corps. that no bridge lifts would occur during the time the reversible lane was in operation.

HOV Strategies

Regional travel demand modeling and FREQ traffic operations modeling were performed on the three HOV strategies described previously:

- **Full Corridor Option**: HOV lanes from 134th Street in Washington to approximately Lombard Street (southbound) or Going Street (northbound) in Oregon including a reversible HOV lane, utilizing a fixed barrier across the Interstate Bridge and a movable barrier through Delta Park
- **Delta Park Option**: A reversible HOV lane only in the portion of the corridor where the existing northbound HOV lane is located (southbound the HOV lane would end near Lombard Street)
- **Queue Bypass Option**: The addition of an AM peak southbound HOV lane in Washington similar to the current PM northbound HOV lane in Oregon. Further analysis includes determining if the HOV lane should be re-started on the other side of the Interstate Bridge

The following table summarizes the southbound lane configuration options for the various HOV options modeled:

Table 4. Southbound Lane Configuration Options

Scenario Name	Configurations			
	134th to SR 500	SR 500 to Mill Plain	Mill Plain to Jantzen Beach	Delta Park
No New HOV	3GP	3GP	3GP	2GP
Queue Bypass 1(A)	2GP + HOV	2GP + HOV	3GP	2GP
Queue Bypass 1(B)	3GP + HOV	3GP + HOV	3GP	2GP
Queue Bypass 1(C)	2GP + HOV	3GP + HOV	3GP	2GP
Queue Bypass 1(D)	2GP + HOV	3GP	3GP	2GP
Queue Bypass 2(A)	2GP + HOV	3GP + HOV	3GP	2GP + HOV
Queue Bypass 2(B)	3GP + HOV	3GP + HOV	3GP	2GP + HOV
Queue Bypass 2(C)	2GP + HOV	3GP	3GP	2GP + HOV
Full Corridor HOV	2GP+HOV	3GP+HOV	3GP+HOV	2GP+HOV
Delta Park only	3GP	3GP	3GP	2GP + HOV

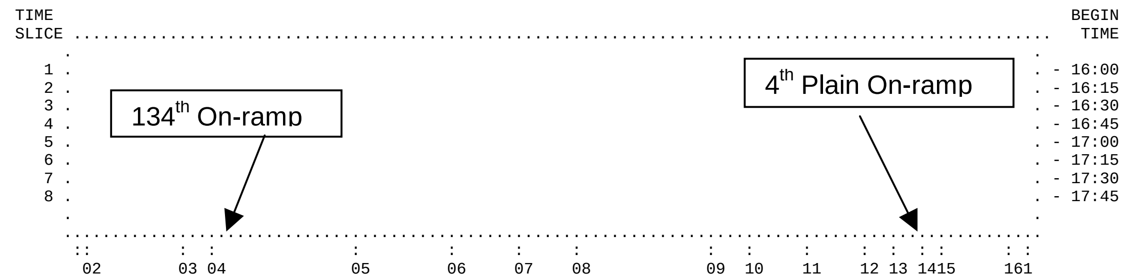
GP = General purpose lanes

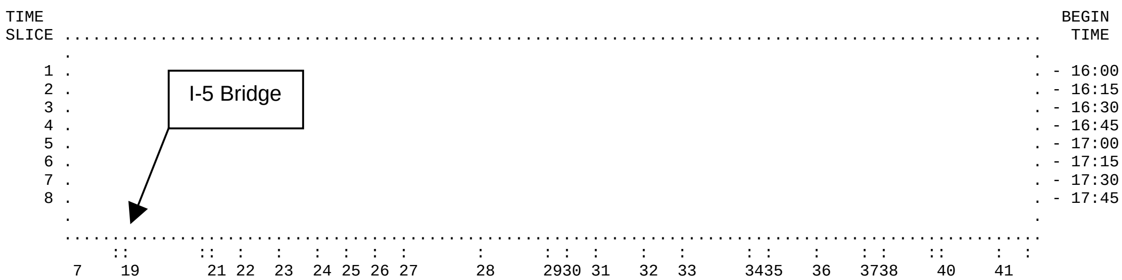
PM PEAK REVERSIBLE LANE IMPACTS ON NON-PEAK TRAFFIC

An analysis was made of impacts of a northbound PM peak reversible HOV lane on the southbound (non-peak) traffic direction. Shown below are the queue diagrams and summary statistics. **Figure 11** shows the FREQ queue contour with the No-New HOV option (three general purpose lanes southbound), and the northbound Reversible Lane with two general purpose lanes southbound across the Interstate Bridge.

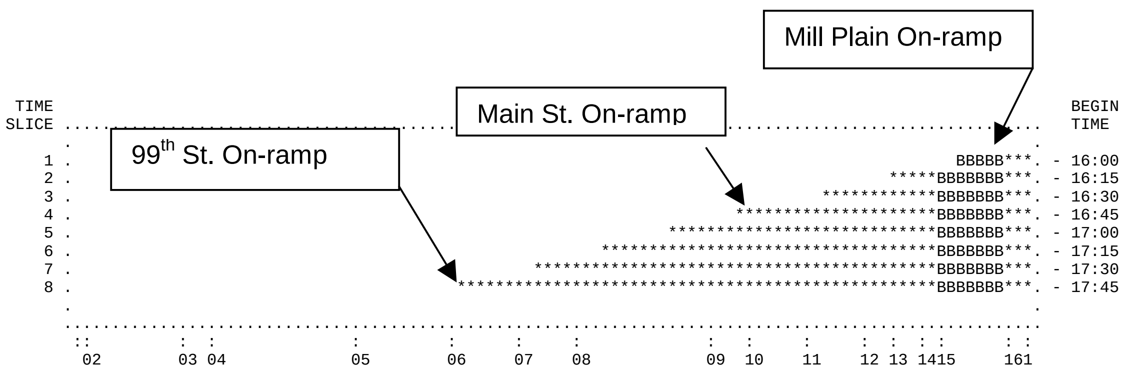
Figure 11. Queue Contour Diagram

2020 Southbound PM Peak Analysis: 3 Southbound Lanes Across Interstate Bridge





2020 Southbound PM Peak Analysis: 2 Southbound Lanes Across Interstate Bridge



BLANK DENOTES MOVING TRAFFIC. ASTERISK DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION.
M DENOTES QUEUED VEHICLES DUE TO MERGING. B DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION AND MERGING. (WHEN BOTH QUEUES EXIST, LENGTH OF DISPLAY REPRESENTS MAINLINE CONGESTION.)

SUMMARY OF IMPACTS OF PM PEAK REVERSIBLE LANE ON SOUTHBOUND TRAFFIC

This shows a significant increase in delay and overall travel time by removing one southbound travel lane on the Interstate Bridge and converting it to a northbound HOV lane.

Table 5. Southbound I-5 Non-Peak Direction (4-6 PM)

Measure of Effectiveness		2020 Base (3 southbound lanes)	2020 Full Corridor HOV (2 southbound lanes)
(southbound during PM peak hr (4-6 p.m.))	**Unit**	**No New HOV**	**Reversible HOV Lane**
Average Speed	mph	53.0	27.2
Freeway travel time from 4-6 p.m.	Vehicle-hours	2059	3522
	Passenger-hours	2454	4198
Travel Distance	vehicle-miles	109,099	95,670
	passenger-miles	130,046	114,039
Overall mainline delay	vehicle-hours	37	1701
4:30 p.m.	minutes/vehicle	0.07	2.60
5:30 p.m.	minutes/vehicle	0.07	7.32

Based on this information, the TAC recommended eliminating consideration of a PM peak, northbound reversible HOV lane across the Interstate Bridge.

At the Phase II Peer Review, the TAC also agreed that any options that included a reversible lane across the Interstate Bridge be dropped from further consideration. This was based on the following findings by the TAC:

- The reversible lane widths of 10.5 feet are substandard for a 50 mph Interstate Highway and would require a permanent speed limit reduction to a maximum of 45 mph.
- C-TRAN buses likely would not use these narrow lanes due to high potential for collisions between bus mirrors and mirrors of large vehicles in the opposing traffic direction.
- The reversible lane design would require special design treatments to accommodate the lift span, which would either pose a safety hazard by breaking the barrier on the lift span or have a potential to add significant traffic stoppage time to bridge lifts in order to remove the barrier from the lift span.
- The potential time savings for HOV users of 1.9 additional minutes per HOV vehicle with the Full Corridor option (12 minutes per vehicle) compared to no HOV across the bridge (10.1 minutes per vehicle) was insufficient to overcome the increased risk of safety and incident management problems associated with the reversible lane operations.

FINDINGS OF HOV EVALUATION

Tables 6 and 7 summarize various modeling results applying some of the HOV evaluation criteria. FREQ queue contours are summarized in **Figures 12 through 15** for southbound HOV alternatives and **Figures 16 and 17** summarize the northbound HOV analysis. Additional tables are contained in **Appendix A**.

Table 6. HOV Measures Summary

	Measured at Marine Drive				Measured at Mill Plain Boulevard						
Alternative	**Vehicles in HOV Lane**	**Bus Ridership**	**Persons in HOVs**	**Total Persons on Corridor**	**Vehicles in HOV Lane**	**Persons in HOVs**	**Bus Ridership**	**Total Persons on Corridor**	**Person Hours Traveled**	**HOV Lane Time Savings (Minutes per Vehicle)**	**HOV Lane Time Savings (Minutes per Mile)**
AM Peak 2-Hour Period											
Base-Case: No New HOV	N/A*	1,720	4,000*	15,184	N/A*	3,640*	1,720	15,200	9,241	-----	N/A
Full Corridor HOV	1,860	1,900	5,350	15,090	1,700	5,760	1,900	17,400	7,455	12	1.1
Washington-only HOV (Queue Bypass 1)	N/A*	1,800	4,900*	15,106	1,400	4,630	1,800	16,170	8,404-8,531	7-8	1.1
HOV in Delta Park only	1,000	1,760	4,370	14,970	N/A*	4,060	1,760	15,600	9,307	1.8	0.7
HOV in Washington and Oregon (Queue Bypass 2)	***1,530***	***1,900***	***5,120***	***14,700***	***1,400***	***4,900-5,190***	***1,900***	***16,680-16,750***	***8,459***	***9-10***	***1.1 – 1.2***
PM Peak 2-Hour Period											
Base-Case: No New HOV	1,860	1,880	5,510	16,850					12,792+	10 - 11	3.0
Full Corridor HOV	2,040	1,900	5,900	18,154					8,629+	9-10	0.9
Oregon-only HOV (Queue Bypass 1)	***1,860***	***1,880***	***5,510***	***16,850***					***12,792+***	***10-11***	***3.0***
HOV in Washington and Oregon (Queue Bypass 2)	1,860	1,800	5,460	16,800					Not summarized	7-8	0.8

N/A*: No HOV lane at this location in this alternative
+: Summarized for 5-hour PM peak period.

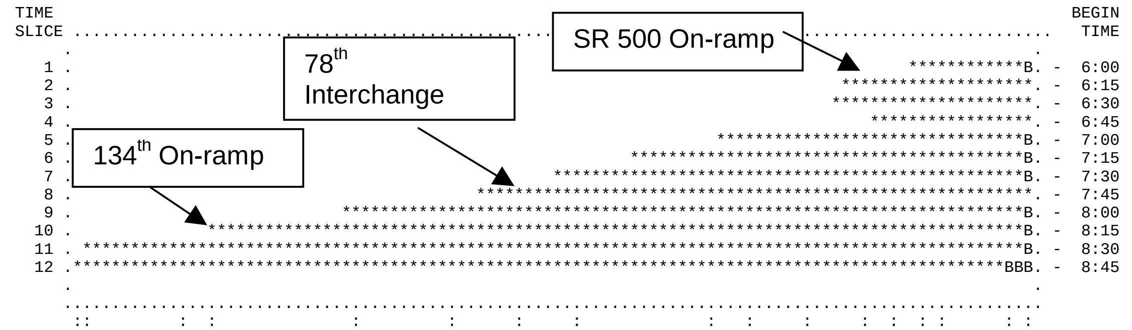
Bold Italics: Selected HOV alternative

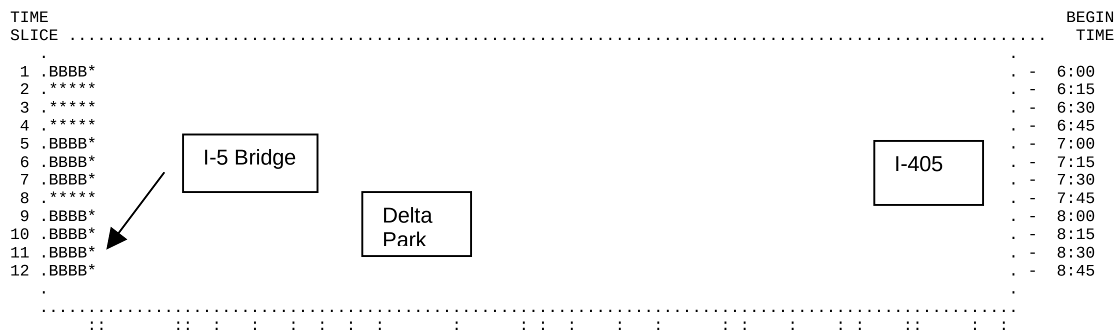
Table 7. HOV Measures of Effectiveness Compared to No New HOV

Measure	Queue Bypass #1A	Queue Bypass #1B	Queue Bypass #1C	Queue Bypass #1D	Queue Bypass #2	Queue Bypass #2B	Queue Bypass #2C	Delta Park Only
Total Person Throughput	+	+	+	O	+	+	+	O
HOV lane usage >500 vehicles per hour	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	Borderline
HOV time savings > 5 minutes over GP	**Yes (7.1)**	**Yes (7.4)**	**Yes (7.4)**	**Yes (5.5)**	**Yes (10.0)**	**Yes (10.5)**	**Yes (9.0)**	No (1.8)
HOV time savings > 1 minute per mile	**Yes (1.3)**	**Yes (1.3)**	**Yes (1.3)**	**Yes (1.3)**	**Yes (1.1)**	**Yes (1.2)**	**Yes (1.0)**	No (0.7)
GP Mainline Delay	**Lower**	**Lower**	**Lower**	**Lower**	**Lower**	Higher	Higher	Same
Total Mainline Delay	**Lower**	**Lower**	**Lower**	**Lower**	**Lower**	Higher	Higher	Same
Overall Average Speed	+	+	+	+	O	O	-	O
HOV Lane Persons > GP Persons Per Lane	**Yes**	**Yes**	**Yes**	N/A*	**Yes**	**Yes**	**Yes**	N/A*
HOVs Induced	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No
HOVs Diverted from Other Corridor(s)	Possibly	Possibly	Possibly	Possibly	**Yes**	**Yes**	**Yes**	No
Park-and-Rides/ Transit Centers with Access to HOV Lane	**3**	**3**	**3**	**2**	**4**	**4**	**3**	**4**

Bold measures are positive impacts, benefits or results
* No HOV Lane at measurement point

Figure 12. 2020 “No New Hov Base” Queue Contour Diagram Southbound





BLANK DENOTES MOVING TRAFFIC. ASTERISK DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION.
M DENOTES QUEUED VEHICLES DUE TO MERGING. B DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION AND MERGING. (WHEN BOTH QUEUES EXIST, LENGTH OF DISPLAY REPRESENTS MAINLINE CONGESTION.)

Figure 13. 2020 “No New HOV Base” Queue Contour Diagram Northbound

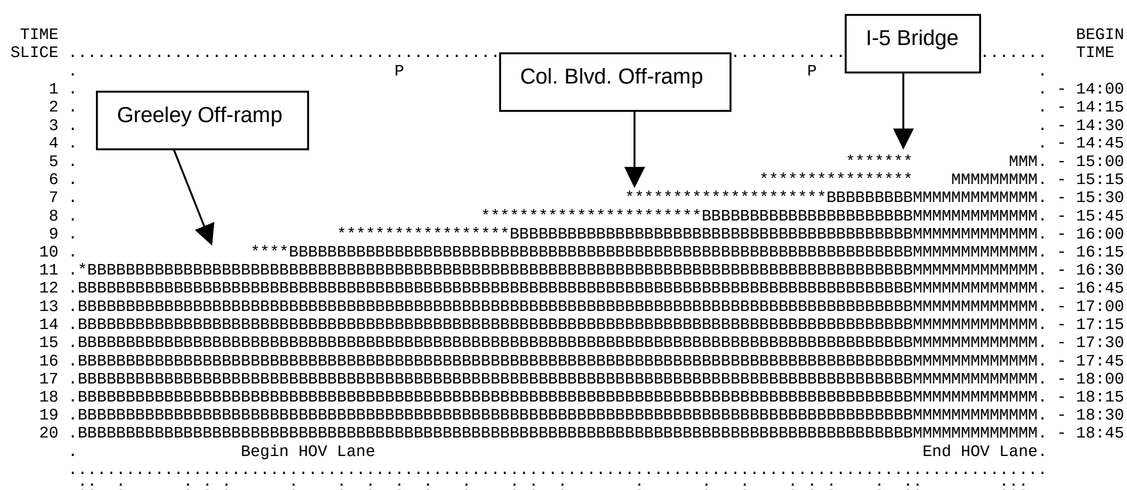


Figure 13 (Continued). 2020 "No New HOV Base" Queue Contour Diagram Northbound

```
TIME                                                                                                          BEGIN
SLICE ......................................................................................................   TIME
      .                                                                                                    .
   1  .              M                                                                                     . - 14:00
   2  .            MMM                                                                                     . - 14:15
   3  .       MMMMMMMM                                                                                     . - 14:30
   4  .  MMMMMMMMMMMMM                                                                                     . - 14:45
   5  .MMMMMMMMMMMMMMMM                                                                                    . - 15:00
   6  .MMMMMMMMMMMMMMMM                                                                                    . - 15:15
   7  .MMMMMMMMMMMMMMMM                                                                                    . - 15:30
   8  .MMMMMMMMMMMMMMMM                                                                                    . - 15:45
   9  .MMMMMMMMMMMMMMMM                                                                                    . - 16:00
  10  .MMMMMMMMMMMMMMMM                                                                                    . - 16:15
  11  .MMMMMMMMMMMMMMMM                                                                                    . - 16:30
  12  .MMMMMMMMMMMMMMMM                                                                                    . - 16:45
  13  .MMMMMMMMMMMMMMMM                                                                                    . - 17:00
  14  .MMMMMMMMMMMMMMMM                                                                                    . - 17:15
  15  .MMMMMMMMMMMMMMMM                                                                                    . - 17:30
  16  .MMMMMMMMMMMMMMMM                                                                                    . - 17:45
  17  .MMMMMMMMMMMMMMMM                                                                                    . - 18:00
  18  .MMMMMMMMMMMMMMMM                                                                                    . - 18:15
  19  .MMMMMMMMMMMMMMMM                                                                                    . - 18:30
  20  .MMMMMMMMMMMMMMMM                                                                                    . - 18:45
      .                                                                                                    .
      ......................................................................................................
         : :      :    :   :     :  :     :             :    :      :          :                :  :      :
```

4th Pl. On-ramp to SR 500 Off-ramp

134th St.

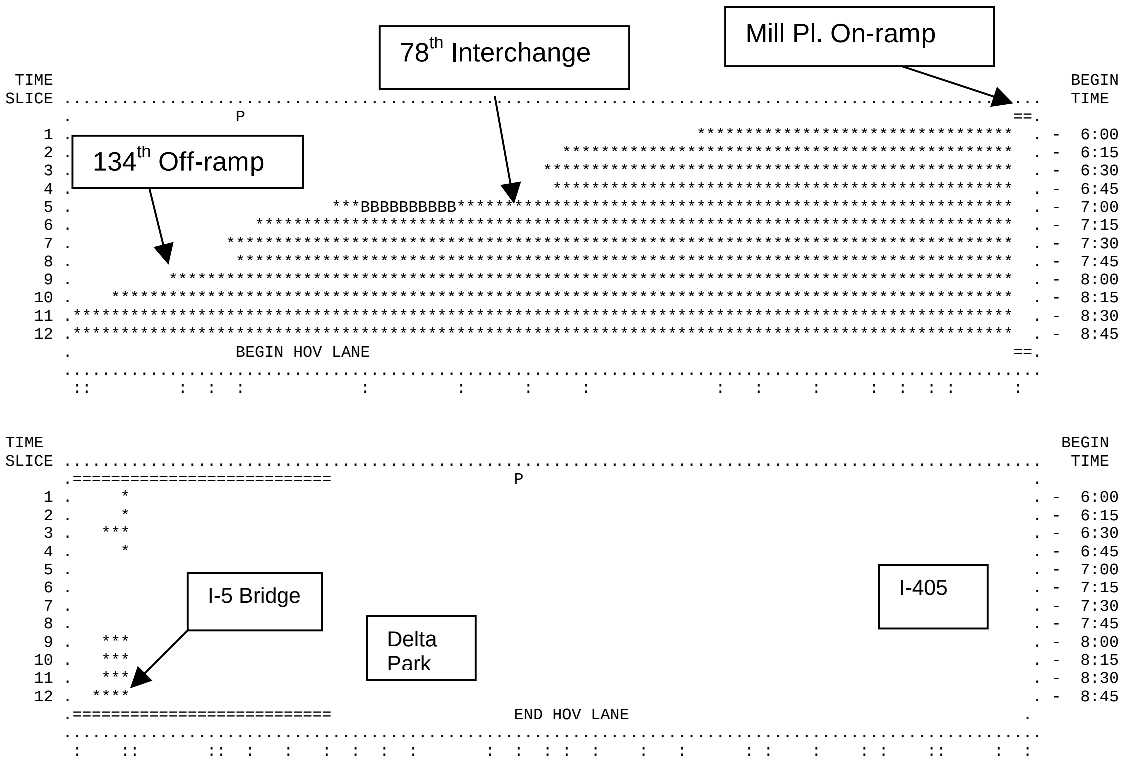
```
P  PROPOSED LOCATION FOR THE PRIORITY LANE(S)  P

BLANK DENOTES MOVING TRAFFIC.  ASTERISK DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION.
 M  DENOTES QUEUED VEHICLES DUE TO MERGING.  B  DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION AND
 MERGING.   (WHEN BOTH QUEUES EXIST, LENGTH OF DISPLAY REPRESENTS MAINLINE CONGESTION.)
```

No New HOV Findings

- Throughout I-5, projected peak direction travel demands will exceed available capacities between 6 and 9 a.m. and between 3 and 7 p.m., resulting in extended periods of congestion and substantially reduced travel speeds within and outside of these periods.
- In the northbound direction, the queue south of the I-5 Bridge does not start until 3:00 p.m. The queue reaches the end of the corridor (I-84) by 4:30 p.m.
- In the southbound direction, the queue south of the I-5 Bridge starts before 6:00 a.m. The queue reaches the end of the corridor (I-205) at 9:00 a.m.
- The average speed for the HOV lane over the entire 2-7 p.m. time period is 47.8 mph.
- The northbound vehicle occupancy mix: 74.3 percent single occupant vehicles, 23.7 percent two-person HOVs, 1.4 percent three-plus HOVs, 0.2 percent motorcycles, and 0.4 percent buses.
- The southbound vehicle occupancy mix: 89.6 percent single occupant vehicles, 9 percent two-person HOVs, 1 percent three-plus HOVs, 0.2 percent motorcycles, and 0.2 percent buses.
- The ***demand volume*** is a measure of the number of vehicles desiring service in the given time period, not the number that can be served.

Figure 14. 2020 “Full Corridor HOV” Queue Contour Diagram



P PROPOSED LOCATION FOR THE PRIORITY LANE(S) P BARRIER EXTENDS OVER LENGTH OF ==== SYMBOL

BLANK DENOTES MOVING TRAFFIC. ASTERISK DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION.
M DENOTES QUEUED VEHICLES DUE TO MERGING. B DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION AND MERGING. (WHEN BOTH QUEUES EXIST, LENGTH OF DISPLAY REPRESENTS MAINLINE CONGESTION.)

Figure 15. 2020 “Full Corridor HOV” Queue Contour Diagram Northbound

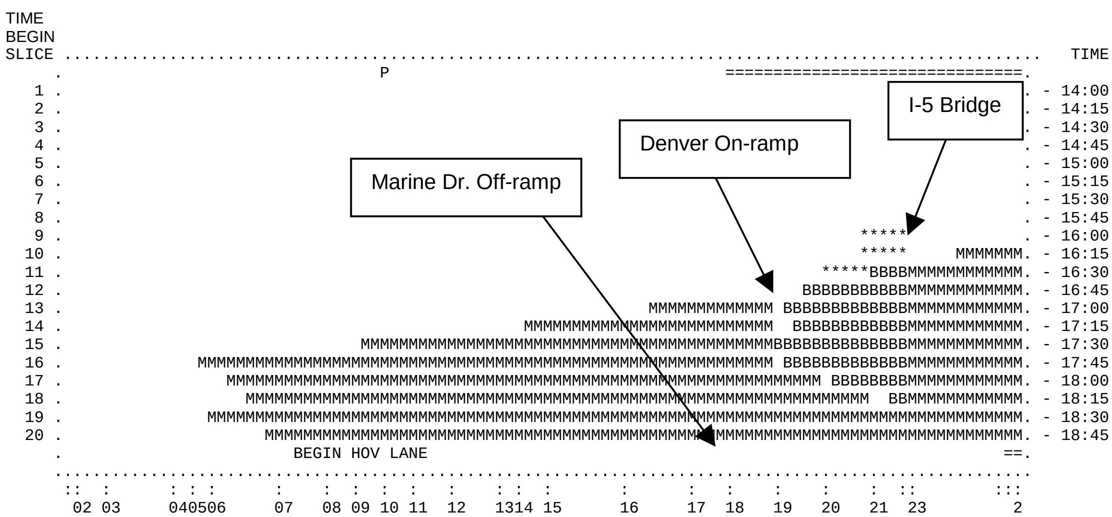


Figure 15 (Continued). 2020 "Full Corridor HOV" Queue Contour Diagram Northbound

```
 TIME                                                                                                        BEGIN
 SLICE ......................................................................................................  TIME
       .=============                                                                            P           .
    1 .                                                                                                      . - 14:00
    2 .                                                                                                      . - 14:15
    3 .                 M                                                                                    . - 14:30
    4 .                 M                                                                                    . - 14:45
    5 .                MM                                                                                    . - 15:00
    6 .                MM                                                                                    . - 15:15
    7 .             MMMMM                                                                                    . - 15:30
    8 .         MMMMMMMMM                                                                                    . - 15:45
    9 .MMMMMMMMMMMMMMMMMM                                                                                    . - 16:00
   10 .MMMMMMMMMMMMMMMMMM                                                                                    . - 16:15
   11 .MMMMMMMMMMMMMMMMMM                                                                                    . - 16:30
   12 .MMMMMMMMMMMMMMMMMM                                                                                    . - 16:45
   13 .MMMMMMMMMMMMMMMMMM                                                                                    . - 17:00
   14 .MMMMMMMMMMMMMMMMMM                                                                                    . - 17:15
   15 .MMMMMMMMMMMMMMMMMM                                                                                    . - 17:30
   16 .MMMMMMMMMMMMMMMMMM                                                                                    . - 17:45
   17 .MMMMMMMMMMMMMMMMMM                                                                                    . - 18:00
   18 .MMMMMMMMMMMMMMMMMM                                                                                    . - 18:15
   19 .MMMMMMMMMMMMMMMMMM                                                                                    . - 18:30
   20 .MMMMMMMMMMMMMMMMMM                                                                                    . - 18:45
      .                                                                            END HOV LANE              .
      .......................................................................................................
          : :     :    :   :     :  :     :              :    :      :          :       :       :  :     :

   P  PROPOSED LOCATION FOR THE PRIORITY LANE(S)  P   BARRIER EXTENDS OVER LENGTH OF ==== SYMBOL

   BLANK DENOTES MOVING TRAFFIC.  ASTERISK DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION.
   M  DENOTES QUEUED VEHICLES DUE TO MERGING.  B  DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION AND
   MERGING.   (WHEN BOTH QUEUES EXIST, LENGTH OF DISPLAY REPRESENTS MAINLINE CONGESTION.)
```

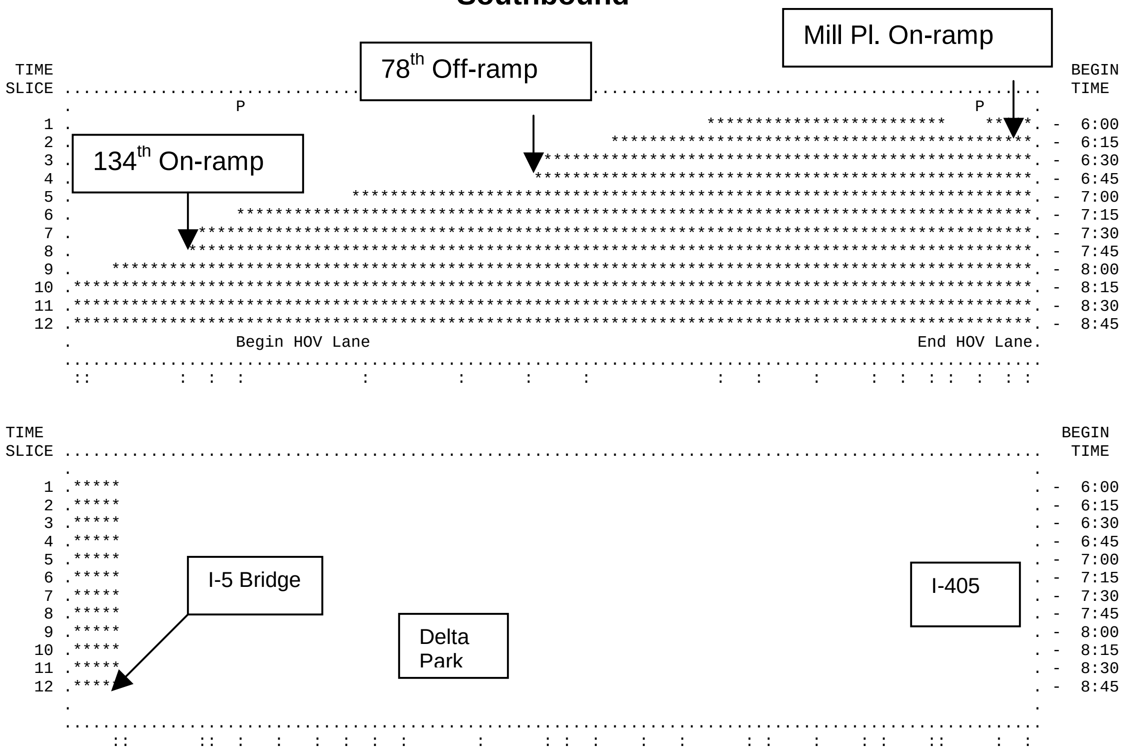
4th Pl. On-ramp to SR 500 Off-ramp

134th St.

Full Corridor HOV Findings

- Throughout I-5, projected peak southbound travel demands will exceed available capacities of the general-purpose lanes between 6 and 9 a.m., resulting in extended periods of congestion and substantially reduced travel speeds within and outside of these periods.
- In the northbound direction the queue begins at the crossover point for the HOV at 4:00 p.m. The problem areas are the merging points at the beginning and end of the crossover HOV lane and the beginning of the I-5 Bridge. These merging locations are Denver On-ramp to Marine On-ramp and 4th Plain On-ramp to SR 500 Off-ramp. The queue from the Denver On-ramp reaches its maximum of Portland Blvd. On-ramp at 5:00 p.m.
- In the southbound direction the queue begins at the crossover point for the HOV at 6:00 a.m. The problem areas are the merging points at the beginning of the crossover HOV lane and the beginning of the I-5 Bridge. The merging locations are 4th Plain On-ramp to Mill Plain Off-ramp and Mill Plain On-ramp to SR 14 Off-ramp. The queue reaches the end of the corridor (I-205) at 8:30 a.m.
- The average speed for the northbound HOV lane over the entire 2-7 p.m. time period is 54.7 mph.
- The average speed for the southbound HOV lane over the entire 6-9 a.m. time period is 57.6 mph.
- The off peak demand volume to capacity ratios for the Interstate Bridge are AM peak (northbound) 0.70, PM peak (southbound) 1.21. The southbound travel lanes are over capacity during the 2-7 p.m. time period.

Figure 16. 2020 "Queue Bypass #1" Queue Contour Diagram Southbound



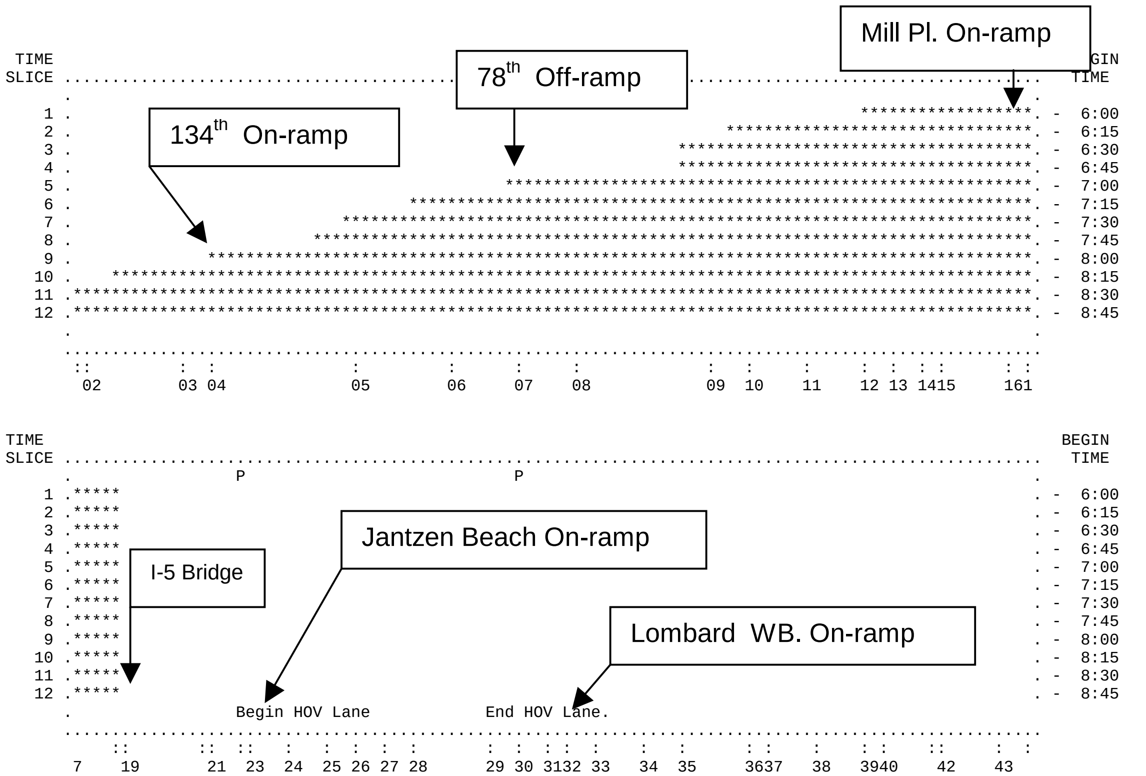
P PROPOSED LOCATION FOR THE PRIORITY LANE(S) P BARRIER EXTENDS OVER LENGTH OF ==== SYMBOL

BLANK DENOTES MOVING TRAFFIC. ASTERISK DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION.
M DENOTES QUEUED VEHICLES DUE TO MERGING. B DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION AND MERGING. (WHEN BOTH QUEUES EXIST, LENGTH OF DISPLAY REPRESENTS MAINLINE CONGESTION.)

Queue Bypass #1 HOV Findings

- Throughout I-5, projected peak direction travel demands will exceed available capacities between 6 and 9 a.m., resulting in extended periods of congestion and substantially reduced travel speeds within and outside of these periods.
- In the southbound direction, the queue south of the I-5 Bridge starts before 6:00 a.m. The queue reaches the end of the corridor (I-205) at 8:15 a.m.
- The average speed for the HOV lane over the entire 6 - 9 a.m. time period is 60.1 mph.
- Northbound is the same as "No New HOV."

Figure 17. 2020 “Delta Park” Queue Contour Diagram Southbound



P PROPOSED LOCATION FOR THE PRIORITY LANE(S) P BARRIER EXTENDS OVER LENGTH OF ==== SYMBOL

BLANK DENOTES MOVING TRAFFIC. ASTERISK DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION.
M DENOTES QUEUED VEHICLES DUE TO MERGING. B DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION AND MERGING. (WHEN BOTH QUEUES EXIST, LENGTH OF DISPLAY REPRESENTS MAINLINE CONGESTION.)

Delta Park Findings

- Throughout I-5, projected peak direction travel demands will exceed available capacities between 6 and 9 a.m., resulting in extended periods of congestion and substantially reduced travel speeds within and outside of these periods.
- In the southbound direction, the queue south of the I-5 Bridge starts before 6:00 a.m. The queue reaches the end of the corridor (I-205) at 8:30 a.m.
- The average speed for the HOV lane over the entire 6 - 9 a.m. time period is 51.6 mph.
- GP speeds south of the Interstate Bridge are in the high 40-mph range, which are comparable to the HOV speeds. Due to the high speeds in the GP lanes, there is minimal mode shift from SOV to HOV.
- Northbound is the same as “No New HOV.”

FINDINGS AND CONCLUSIONS

Based on the analysis conducted of the various alternatives, the following technical findings are reached:

Mobility

- Northbound north of the Interstate Bridge, due to the metering effect of the Interstate Bridge, there are little or no travel time savings expected for HOV users compared to general purpose lanes.
- Southbound, a bi-state I-5 HOV facility provides the greatest mobility by increasing the number of person trips using the corridor and reducing overall vehicle hours of travel compared to other HOV alternatives and to the provision of general purpose capacity.
- A review of HOV alternatives show the alternatives which include a southbound HOV lane between 134th Street and the Interstate Bridge and through Delta Park (Oregon-Washington Queue Bypass, Full Corridor) save HOV users approximately 8 to 12 minutes per vehicle compared to general purpose lanes, and over one minute per mile.
- There is a 2-minute additional HOV travel time savings with the Full Corridor Option compared to the Oregon and Washington Queue Bypass option. This is attributable to the southbound reversible HOV lane across the Interstate Bridge.
- Most of the projected HOV time savings occurs in Washington (7-8 minutes per vehicle).
- Southbound travel time savings through Delta Park is limited by the capacity constraints of the Interstate Bridge.

Traffic Operations

- In 2020, southbound AM peak congestion occurs for most of the corridor between 134th Street and the Interstate Bridge. Congestion may also occur north of 134th Street for options which have less than three general purpose lanes on I-5 south of 134th Street.
- Northbound in 2020, PM peak congestion occurs for most of the corridor between I-84 (the southern edge of the study area) and the Interstate Bridge.
- The Interstate Bridge meters traffic in each direction, affecting downstream queues both currently and in 2020.
- Approximately one mile of queuing, similar to that currently experienced, is expected through Delta Park in 2020.
- Southbound between SR 500 and the Interstate Bridge, HOV scenarios which added a lane rather than converting an existing lane showed less congestion.

HOV Usage

- The number of persons using the HOV lane exceed the number of persons per lane in the adjacent general purpose lane.
- Bi-state HOV options resulted in the highest number of person trips and HOV lane usage of any of the options.

Interstate Bridge

- Any reversible lane option on the Interstate Bridge reduces travel lane width, impacts traffic operations, and is difficult to design and manage with an operating lift-span drawbridge.
- The northbound PM peak reversible HOV lane across the Interstate Bridge significantly increases congestion in the southbound direction in 2020 due to the loss of a southbound general purpose lane.
- Benefits gained by having a northbound reversible HOV lane on the southbound span of the Interstate Bridge are more than offset by the disbenefits of increased congestion in the southbound direction in the PM peak period.

Cost

- The estimated cost to implement HOV in Washington is approximately $362,000.
- A reversible lane through Delta Park was a design option working within the existing bridge structures over the Columbia Slough and Columbia Boulevard. The substandard nature of its design, including lack of shoulders and left-hand merging areas, presents significant safety and operational concerns, and the $6 million capital cost and $750,000 annual operational costs of the reversible lane could eventually exceed the cost of a major widening project.

Other

- The I-5 Corridor is a National Priority Trade Corridor and HOV facilities should be considered within the context of the overall function of I-5.

The study concluded that:

- No further consideration should be given for a PM peak northbound HOV lane in Washington north of the Interstate Bridge unless warranted by congestion or if new capacity is provided by a replacement of the Interstate Bridge.
- No further consideration should be given for a reversible HOV facility across the existing Interstate Bridge spans.
- A minimum of three general purpose lanes should be provided in each direction in Washington between SR 500 and the Interstate Bridge.
- Although the selected HOV option north of SR 500 is two general purpose lanes plus an HOV lane, the conversion to three general purpose travel lanes plus and an HOV lane should considered when warranted by congestion or when new bi-state capacity is provided by the replacement of the Interstate Bridge.
- A southbound, AM peak period HOV lane through Delta Park should be accomplished via widening of the corridor to achieve three full-time through lanes within acceptable design standards rather than by a peak-only reversible lane.
- Widening of I-5 southbound through Delta Park would provide AM peak period HOV capacity and non-peak freight capacity.

The I-5 Trade Corridor Study should receive and address these conclusions as part of the overall bi-state decision-making process on the I-5 corridor, including the considerations for any new Columbia River crossing capacity.

Results

Based on the findings and conclusions of this study, the TAC recommended the Selected HOV Option which is described in the following chapter. In addition, transportation policy issues which need resolution, especially the Bi-State policy issues, are reviewed in the "Next Steps" chapter of this report:

SUMMARY OF SELECTED HOV ALTERNATIVE

The I-5 HOV Operational Study has developed a set of findings regarding an HOV configuration in I-5 corridor. These findings are based on an analysis of traffic operations, safety, and design issues for the HOV options studied. The findings are that bi-state HOV facility in the I-5 corridor significantly improves mobility in the corridor for transit and other shared ride users. The selected HOV option consists of an AM southbound HOV facility in Washington from 134th Street to Mill Plain Boulevard, no HOV across the Interstate Bridge, and an HOV lane in Oregon from Marine Drive to Lombard Avenue provided by widening through Delta Park to three lanes southbound. In 2020, this option provides almost 9-10 minutes of travel time savings compared to the general purpose lanes. In addition, the HOV lanes lane carries 5,120 persons (in transit and carpools) during the morning two-hour peak period compared to an average of 3,850 persons per lane in the adjacent general purpose travel lanes. The following sections describe the lane configuration by segment:

Washington

- *Two general-purpose travel lanes plus an HOV lane from 134th Street to SR 500*. This would also include an auxiliary add/drop lane from 134th Street to SR 500.
- *Added capacity for HOV from SR 500 to Mill Plain Boulevard*. This would be accomplished by reconfiguration of the existing lane and shoulder striping to provide an additional through (HOV) lane in this segment. There are two possible design options for this reconfiguration:
  - A new outside general purpose lane would be added from SR 500 south to the Interstate Bridge and the inside general purpose lane would be utilized for HOV; the HOV lane designation would drop at Mill Plain Boulevard to allow all vehicles to use the inside lane across the bridge; or
  - An HOV lane would be added to the inside median which would then merge with general purpose traffic before crossing the Interstate Bridge. The tradeoffs between the two design options have been defined and should be considered in the decision-making process for HOV implementation.

Interstate Bridge *No HOV lane across the bridge*.

Oregon

Added capacity for HOV from Marine Drive to Lombard Avenue. The study concluded that a reversible HOV lane within the existing highway section was unacceptable due to safety and operational concerns. Therefore, southbound HOV capacity is to be provided by constructing an additional travel lane on Interstate 5 from the Delta Park interchange to Lombard Ave. This project is included in the RTP strategic plan and ODOT has begun preliminary work on the project. The project was also recommended by the I-5 Trade Corridor Leadership Committee.

The following tables summarize the recommended Selected HOV Alternative impacts compared to the No-New HOV base case.

Table 8. AM Peak Period Summary

HOV Strategy	Person Hours Traveled	Vehicle Trips	General Purpose Vehs.	Bus Persons	HOV Persons	Total Person Trips+	Persons Per Lane, GP	Persons in HOV Lane
2020 Modeling								
***Base Case*: No-New HOV**	**9,241**	**10,600**	**9,600**	**1,700**	**1,960**	**15,200**		
Selected	**8,852**	**11,100**	**9,630**	**1,900**	**3,220**	**16,680**	**3,850**	**5,120**
2003 Modeling								
No New HOV		**8,400**	**7,480**	**1,000**	**1,580**	**10,800**		
Selected		**8,400**	**7,450**	**1,100**	**2,030**	**11,325**	**2,730**	**3,130**

\+ Measured at Mill Plain Boulevard

Source: RTC; PB using Charles River Associates' HOV Model; adjustments based on FREQ and regional model results.

A schematic showing the lane configuration is shown in **Figure 18**.

Cost estimates for the reversible lane design and for implementing HOV in Washington concept are contained in **Appendix A**.

Figure 18. Lane Configuration Schematic

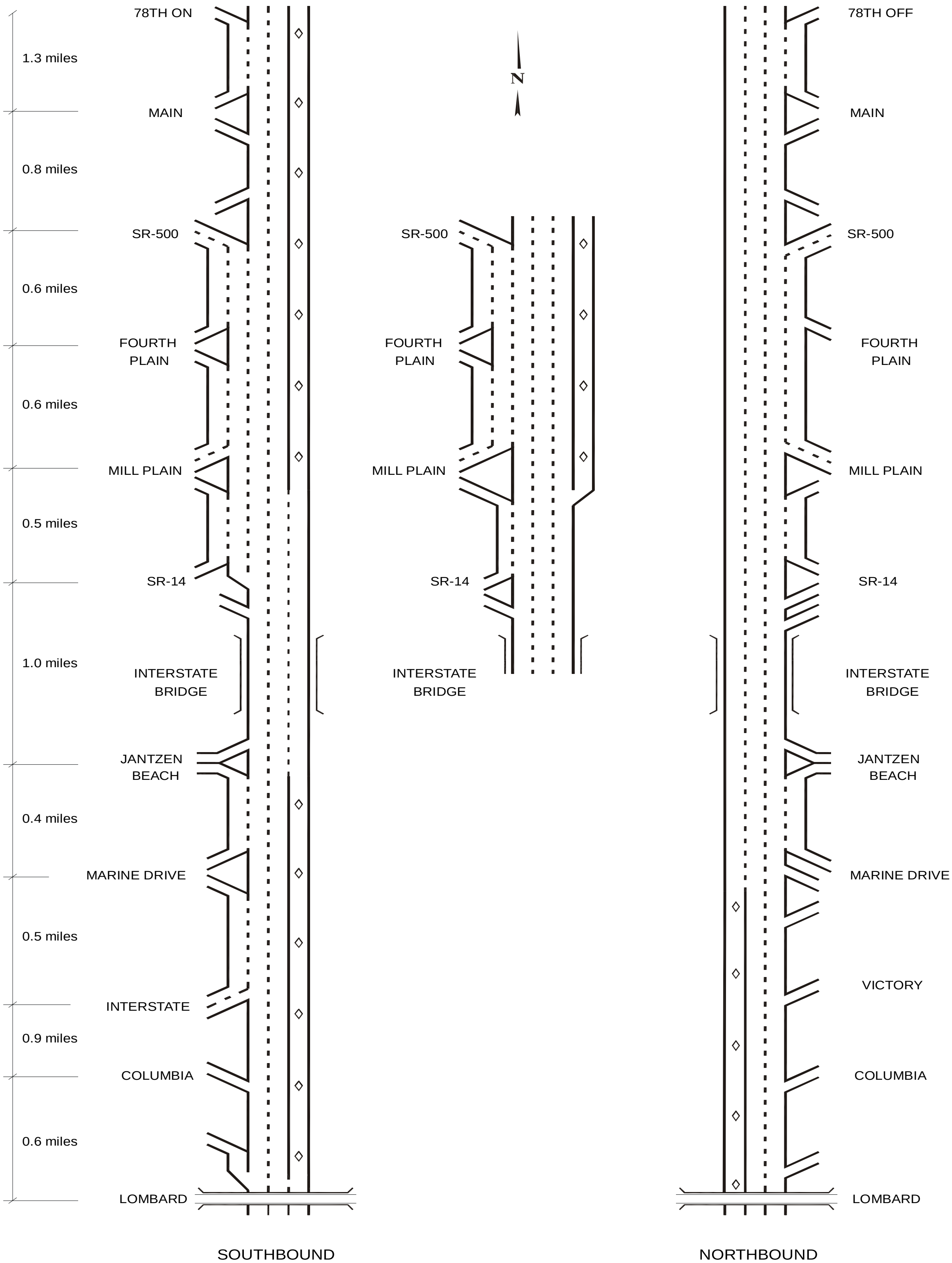


Table 9. Opening Year

	Carpool Vehicles	Buses	Total HOV Vehicles
HOV Lane Usage, No Diversion from I-205	500	10	510
Expected Diversion from I-205	100	0	100
Adjustment for Higher Utilization*	60	0	60
Total Anticipated HOV Lane Usage Per Hour	660	10	670
Minimum Threshold			500-600

*HOV models assume 70 percent of corridor HOVs will use the HOV lane. Experience with the Northbound HOV lane indicate that this rate is approximately 86 percent for the I-5 corridor. The adjustment, to be conservative, is to estimate an increase of 10 percent in the number of HOV's.

From Charles River Model – AM Peak Hour

Measured at Mill Plain HOV Lane Endpoint

Table 10. Travel Time Savings – Opening Year

Alternative	Washington-Only		Washington Plus Oregon	
	Total Time Savings	Savings Per Mile	Total Time Savings	Savings Per Mile
2GP + HOV	3.7	0.6	5.0	0.6

Implementation of Selected HOV Alternative

Short Term

- Move forward with HOV Strategies in the I-5 Corridor
- Implement the Queue Bypass 2 Alternative
- Implement 2GP + HOV north of SR 500 to 78th Street
- Implement 3GP + HOV between SR 500 and Mill Plain and lane reconfigurations between SR 500 and SR 14 southbound
- No Reversible HOV lanes on the Interstate Bridge
- Consider southbound HOV in Oregon between Jantzen Beach and Lombard or Portland Boulevard with completion of a southbound widening project
- Current HOV lane northbound in the PM peak

These would be implemented when specific thresholds have been met. The thresholds are as follows:

- HOV would save users 1 minute per mile and a minimum of 5 minutes overall (only the current northbound PM peak HOV lane meets this)
- HOV lane is forecast to carry at least 600 vehicles per hour (would barely be met southbound in 2003, is well-met in 2020)
- The HOV lane is expected to carry more persons per hour than any adjacent GP lane (barely met southbound in 2003, well-met in 2020)

- General purpose lanes are experiencing LOS E/F conditions for at least 2 miles in the peak direction over at least 1 peak hour in that direction (i.e., at least 2 miles of LOS E/F in the AM peak southbound, at least 2 miles of LOS E/F in the PM peak northbound)

These mostly apply to the southbound HOV lane in Washington, as the northbound lane currently meets these criteria. For an HOV lane extension (i.e., implementing the HOV lane on the other side of the Interstate Bridge – for example, through Delta Park southbound in the AM once HOV has been implemented in WA, and vice versa for the PM peak), the following are guidelines for considering an HOV extension project:

- The threshold for the main HOV segment (see above) must have been met
- HOV extension must save at least 1 minute per mile, with a minimum additional time savings of 3 minutes
- HOV extension must be at least 2 miles long and bypass a quantified queue
- Traffic in the adjacent GP lanes along the segment for the extension under consideration must operate at LOS E/F in the peak direction for at least 1 hour per day

These thresholds should allow for adequate time to monitor and program HOV implementation project(s).

LONG TERM

- WSDOT should consider conversion to 3GP + HOV north of SR 500 when congestion levels warrant and if new capacity is provided on I-5 across the Columbia River
- WSDOT and the City of Vancouver should consider adding a Bus/HOV ramp meter bypass to the SR 14/Washington Street southbound on-ramp, if the I-5 corridor is improved, including this interchange and the Interstate Bridge

POTENTIAL MITIGATION MEASURES

The following could be considered for implementation if congestion levels impact the HOV time savings for southbound HOV lane usage:

- Converting the Washington Street on-ramp to I-5 southbound to Bus/HOV only in the AM peak period; OR
- Implement a no-left-turn restriction during the AM peak period from 5th Street onto Washington Street to eliminate traffic diverting from SR 14 westbound onto the City Center exit to avoid ramp meter queues

WSDOT HOV Policy and Selected HOV Alternative

The following is a summary of the WSDOT Freeway HOV System Policy and how the Selected HOV Alternative compares.

GENERAL HOV POLICY STATEMENT

1 *WSDOT regards the HOV system as a high capacity transportation system whose goal is to maximize people moving capability of the state highway system, mitigate transportation-related pollution, and reduce dependency on fossil fuels.*

The Selected HOV Alternative increases the peak period person throughput on I-5 by approximately 8 percent over the No-New HOV Alternative. In the AM peak period for 2020, the Selected HOV Alternative carries 16,700 persons in the AM peak period versus 15,200 for the No-New HOV Alternative. In the PM Peak, the Selected HOV Alternative is the existing Northbound-only HOV lane in Oregon. The evaluation of this lane indicates the person throughput on Northbound I-5 has increased by approximately 8-10 percent in the PM peak period over the general purpose lane configuration.

2 *Through the state transportation planning process and regional transportation planning organizations, WSDOT shall take a pro-active role in promoting and coordinating the development of HOV systems, transportation demand management activities, and related transportation system management activities. This will be accomplished through support of local jurisdictions and participation in their transportation and land-use planning efforts statewide.*

WSDOT has been a member of the study's Technical Advisory Committee, which is comprised of local and regional agencies.

3 *WSDOT recognizes that an HOV system may not be the only high capacity transit system in a region depending on adopted regional funding strategies and transportation policies. It is believed that in regions such as the Puget Sound, a completed HOV system must be in place to meet federal environmental clean air standards, and support overall mobility needs and high capacity transportation systems of the future.*

The Metropolitan Transportation Plan designates I-5 as a High Capacity Transit corridor.

4 *All policies adopted by WSDOT regarding this system shall be based on providing incentives for people to shift from single-occupant vehicles to ridesharing modes.*

The Selected HOV Alternative is projected to increase person throughput on the corridor by at least 8 percent over the No-New HOV alternative. The HOV lane provides an incentive for people to shift into ridesharing modes by providing for an opportunity for significant travel time savings and reliability.

5 *WSDOT's aim is to enhance Washington's quality of life, protect the natural environment, preserve mobility for people today, and ensure personal mobility in the year 2000 and beyond.*

These goals are consistent with the goals of the Clark County High-Occupancy Vehicle Study and Metropolitan Transportation Plan.

HOV COORDINATION BETWEEN AGENCIES AND MODES

Policy

1 *Coordination is an essential aspect of a successful HOV program. WSDOT shall coordinate HOV efforts with regional and local transportation agencies throughout the planning, design, construction, and operation phases.*

WSDOT has coordinated with the Regional Transportation Council and the Oregon Department of Transportation on this project, as well as being a member of the multi-jurisdictional Technical Advisory Committee which includes local transportation agencies.

2 *Intermodal considerations and coordination shall take place throughout the HOV planning and development phases.*

The TAC includes C-TRAN in its membership. The HOV Operational Study has coordinated with the I-5 Trade Corridor Study, which is examining freight modes and mobility on the same corridor.

3 *When changes are to occur to the HOV System, WSDOT shall coordinate such change through a regional process, as designated by the Washington State Transportation Commission and described in Washington's Transportation Plan.*

The proposed additions to the HOV System are being coordinated through a regional study being administered by the Regional Transportation Council (RTC).

HOV LANE MINIMUM THRESHOLDS

Policy

HOV lanes are appropriate improvements when current traffic congestion conditions and/or forecasted traffic congestion meet the following criteria:

1 *Facility demand exceeds capacity for more than an hour each day as evidenced by level of service E or F*.

The I-5 corridor currently experiences LOS E/F conditions in the AM peak period (6:30 to 8:30 AM) between 78th Street and Lombard Street southbound, and northbound in the PM peak period between 3 and 6 PM.

2 *Evidence exists that during peak hours of operation, the HOV lane will move more people than the per lane average of the adjacent general purpose lanes*.

The Selected HOV Alternative is estimated to increase the person throughput on I-5 by approximately 8 percent over the No-New HOV Alternative. In the AM peak hour for 2020, estimates indicate that the Selected HOV Alternative will carry over 2,550 persons per hour in the HOV lane versus 1,900 persons per lane per hour for the adjacent general purpose lanes. In the PM Peak, the Selected HOV Alternative is the existing Northbound-only HOV lane. The evaluation of this lane indicates the person throughput on Northbound I-5 has increased by approximately 8-10 percent in the PM peak period over the general purpose lane configuration. The HOV lane is carrying over 2,400 persons per hour compared to 1,600 persons per lane per hour in the adjacent general purpose lanes.

3 *Local support for construction of the HOV lane is demonstrated through active regional support or public surveys*.

Public opinion surveys, including the recently-completed survey for the I-5 HOV Operational Study, continue to show that the majority of respondents support the concept of HOV lanes on I-5. Active regional support is reflected in the recommended HOV alternative, and comments received from the Regional Transportation Advisory Committee and the RTC Board of Directors.

4 *An HOV route segment may also be justified if it enhances HOV system continuity, for example by providing a link between HOV corridors identified in the Freeway Core HOV Lane System.*

The RTC Board adopted the recommendations of the Clark County High Occupancy Vehicle Study, which is an HOV System Plan for the region. Development of an I-5 HOV corridor is the first component of that system.

HOV SPEED AND RELIABILITY STANDARD

Policy

1 *It is WSDOT policy to offer a reliable speed and travel time advantage to HOVs, both to offer an incentive to use ridesharing modes and to enhance person carrying capacity into the future. For transit riders especially, a reliable trip time is equally as important as a fast travel speed.*

It is projected that the implementation of the Selected HOV Alternative will save southbound HOV users approximately 12 minutes in travel time per vehicle in the AM peak period compared to general purpose users. The existing northbound HOV lane continues to save northbound HOV users 5-7 minutes per vehicle compared to general purpose users. The current and recommended HOV lanes are expected to improve travel time reliability for HOV users and on-time bus performance for C-TRAN.

2 *HOV lane vehicles should maintain or exceed an average speed of 45 mph or greater at least 90 percent of the times they use that lane during the peak hour (measured for a consecutive 6-month period).*

Current northbound HOV speeds average 45 to 55 mph. The 2020 projections indicate that the southbound HOV lane is expected to operate at 45-60 mph. Short-term analysis (2003) indicates that the southbound HOV lane is expected to operate at 55 – 60 mph.

CARPOOL DEFINITION

Policy

1 *The statewide base carpool definition for limited access freeways is two or more persons.*

The carpool designation for the Selected HOV Alternative is two or more persons plus motorcycles.

2 *Exceptions to the base carpool definition may be made in cases where an HOV lane is operated on a converted roadway shoulder, or where safety may be compromised at higher volumes of HOV traffic due to substandard roadway geometrics or by opening day projected volumes.*

No exceptions to this policy are recommended.

3 *For each new portion of an HOV route segment, the carpool definition shall initially be established during the preliminary engineering phase of the HOV project and shall be carried through the environmental and design report stages, allowing for public and interjurisdictional review and comment.*

There are no recommended changes to the carpool designation.

4 *The carpool definition shall be consistent on an HOV route segment. HOV bypasses or ramps leading to the HOV route segment may be treated differently when it is beneficial to that immediate area.*

The carpool designation is consistent throughout the bi-state I-5 corridor.

5 *Based on results of the HOV System Evaluation, the carpool definition may be increased to mitigate cases where the HOV Speed and Reliability policy is violated. The carpool definition may be decreased to the base definition if it can be demonstrated that the result would increase person volumes without violating the Speed and Reliability policy. This policy allows for variations in the carpool definition by direction.*

There are no recommended changes to the base carpool designation.

6 *Traffic regulations adopted by WSDOT on June 29, 1984, allow authorized vehicles and vehicles meeting the minimum occupancy definition to use state HOV facilities. Authorized vehicles include motorcycles, buses with 20 or more seats, and public transportation vehicles as defined by state law.*

The Selected HOV Alternative may require a modification of this policy to maintain consistency with ODOT's rules regarding the northbound HOV lane. This is recommended for a future issue resolution process prior to opening the southbound HOV lane. Possible issues to resolve are bus definition (differences between ODOT and WSDOT on bus seat limitations) and use by emergency vehicles.

Hours of Operation

Policy

1 *HOV lanes constructed for HOV purposes shall be reserved for buses, motorcycles, carpools, and vanpools meeting minimum occupancy requirements, 24-hours-per-day, seven-days-a-week. This policy does not apply to HOV restriction on ramps.*

The Selected HOV Alternative would require a deviation from this policy. It is recommended that the Selected HOV Alternative be operated as a peak-period only HOV facility.

2 *WSDOT shall solicit private, transit, and local government support in increasing regional efforts to market and educate the general public about the need for a 24-hour, seven-day-a-week HOV lane operating policy.*

Given the recent public opinion survey that showed a regional preference for a peak-period-only HOV facility (66 percent of those surveyed), and the travel demand results which indicated that HOV lanes will provide for benefits only in the peak periods, and given the I-5 Trade Corridor findings that significant 2020 capacity will be needed in the non-peak hours for freight mobility, it is recommended that the Southwest WSDOT Region pursue a policy deviation for a peak-period-only HOV rule.

3 *Variable carpool definitions may be based on time of day.*

No change to the carpool definition is recommended.

HOV Design and Lane Configuration Considerations

Tables 11 and 12 summarize the trade-offs of various configurations for a southbound HOV facility. Table 13 addresses the issue of a reversible HOV lane in Oregon. It describes the key concerns identified by transportation agencies in the consideration of a reversible lane, and the experiences of regions in other parts of the country. Conditions in each area are unique and may not apply to the Vancouver/Portland region, but it does show how other areas have addressed similar concerns.

There are several issues identified during the study that would need to be resolved prior to the implementation of HOV in the corridor. Among them is the relationship of a southbound HOV facility in Oregon with a proposed Delta Park widening project currently under discussion.

A summary of key policy issues that need to be addressed is contained in the Next Steps chapter of this report.

Table 11. Washington HOV Considerations

Issue	Advantages	Disadvantages
NORTH OF SR 500		
2GP + HOV	• Provides for HOV incentives in short term • Allows for auxiliary lanes between interchanges along corridor from 134th Street to SR 500 • Additional GP capacity is not needed in the short term (2003) • Could easily implement HOV in this segment	• May not provide optimum 20-year corridor capacity 2020 queues extended past modeling area • Would require design deviations to restripe for third GP lane in the future
3GP + HOV	• 20-year analysis shows same HOV benefits as 2GP + HOV • Could implement 3GP lanes now, and design deviations to add HOV lanes are easier than for adding GP lanes	• Additional general purpose capacity in short term provides no HOV incentives • Would require auxiliary lane conversion to general purpose lane
SOUTH OF SR 500		
HOV designation drop south of Mill Plain	• Consistent with WSDOT NW Region preference • Provides HOV incentive as HOVs are not forced to merge	• May increase weaving between HOV lane end and the Interstate Bridge
HOV left merge south of Mill Plain	• Allows three GP lanes to be continuous through entire corridor from 134th Street to across Interstate Bridge	• Disincentive to HOV user as time savings is minimized due to forced weave into queued traffic • Seattle has only one example of HOV merging (from the right); this is not the NW Region's preference • Left merges are uncommon

Table 12. Oregon HOV Considerations

<table>
<tr><th>Issue</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><th colspan="3">JANTZEN BEACH TO PORTLAND BOULEVARD</th></tr>
<tr><td>Reversible HOV</td><td>• Allows for HOV implementation without major widening work
• Uses current southbound shoulder in Delta Park to provide some shoulder for northbound traffic
• HOV becomes an additional southbound lane through the corridor segment
• Provides wider northbound travel lanes and shoulder during PM operation</td><td>• Cost of $5.5 to $6 million may not have much salvage value when widening project occurs
• Requires left HOV merge at Lombard
• Takes away a northbound GP lane and causes a left merge northbound during AM operation
• Annual operating costs may be approximately $750,000 (including enforcement)</td></tr>
<tr><td>Minor widening from Interstate Avenue to Columbia Boulevard to add third (HOV) lane</td><td>• Allows for HOV implementation without major widening work
• Alleviates currently substandard merge at Swift Highway
• Previous analysis shows HOV could be extended to Portland Boulevard and creates additional benefit – this allows that option to occur</td><td>• Uncertain impacts as HOV is a lane conversion from Jantzen Beach to Interstate Avenue and then an additional lane south of Interstate Avenue
• Columbia Boulevard would likely become a merge rather than an add-lane; uncertain impacts on ramp which has a high percentage of trucks</td></tr>
<tr><td>Delta-Lombard major widening project to add an additional lane (HOV or GP)</td><td>• Creates long-term capacity in corridor
• Rebuilds corridor to design standards
• Design could accommodate Columbia Boulevard on-ramp as needed
• Previous analysis shows HOV could be extended to Portland Boulevard and creates additional benefit – this allows that option to occur</td><td>• Major project which will take several years to construct and carries the highest capital cost
• Uncertain impacts as HOV is a lane conversion from Jantzen Beach to Interstate Avenue and then an additional lane south of Interstate Avenue</td></tr>
</table>

Further analysis is recommended to resolve these issues. Additionally, when HOV is implemented, the policy difference between Oregon and Washington regarding time-of-day of HOV operations needs to be resolved. Currently, Oregon allows peak period weekday HOV operations while WSDOT requires HOV lanes to operate 24 hours a day, 7 days a week.

Table 13. Agency Concerns Regarding Reversible HOV Lane

Issue	Response	Experience Elsewhere
High capital and operating cost of installing and operating a reversible lane with a movable barrier	• The operating costs for this project would likely come from ODOT's operating budget • This is a regional policy and programming issue that must be addressed prior to implementation	• I-93 in Boston annual O&M cost is $650,000 • Used CMAQ funds for first three years of operations (limit on CMAQ operational coverage) • Determined that reduced capital cost for reversible lane overcame the increased annual O&M costs • Other treatments nationally experience average of $500,000 or more annual O&M costs
Increased congestion in non-peak direction	• Opening year V/C ratio (AM peak) during reversible lane operation would be approximately 0.70; in 2020 it would be approximately 0.9. • The selected HOV alternative is an interim improvement until major corridor improvements are undertaken • Recommend establishing congestion thresholds before implementation and annual monitoring of non-peak travel after implementation (if reversible lane is implemented) and appropriate action if congestion occurs	• Boston has not experienced non-peak congestion • Dallas and New York City reversible lanes have established thresholds for non-peak congestion levels and reversible lane operations • Minimal impacts experienced in Dallas to non-peak traffic

Issue	Response	Experience Elsewhere
End treatments of HOV lane requires left merges in both directions	• ODOT currently has no adopted policy prohibiting left merges • Appropriate advanced signage and active lane control signs should alleviate the concern • Recommend a more detailed risk assessment and safety analysis to respond to concerns	• Boston treatment requires HOV's to merge from left and yield to GP traffic • Some delay to HOV due to merging but not enough to offset time savings resulting from HOV lane • No adverse experience from left merge • WSDOT has a left-merge design policy in effect in Puget Sound region • WSDOT operating left merges for I-5 north of downtown to Northgate (Express Lanes) • Dallas has similar concept on I-30 with no adverse impacts
Driver confusion resulting from lane configuration and control changes for northbound traffic (AM, off-peak, PM)	• Two of the three changes are already occurring (off-peak, PM HOV) • There may be short-term increase in incidents as drivers become accustomed to the traffic operations • Experience elsewhere indicates drivers will adapt to the situation in long term • If designed well and operated accordingly, should not be a problem	• Boston experienced "curiosity factor" and slight increase in incidents in first few months of operation • Boston practiced the movable barrier in the corridor before official opening to demonstrate to drivers the zipper lane concept • Boston had a media outreach process to advertise the movable barrier HOV lane • Operating and entry rules have changed several times and drivers have adapted each time • Dallas reversible lane results in as many as four traffic operations changes per day • No movable barrier project to date has been removed due to driver confusion or safety issues

PEER REVIEW PROCESS

Two Peer Review Panels were convened to provide an expert and independent review of the alternatives and analysis conducted during the study. The first Peer Review reviewed the results of the Screening and Risk Assessment analyses and the three promising HOV alternatives along with the No Additional HOV alternative. The second Peer Review Panel reviewed the results of the HOV evaluation and the findings and conclusions from that work. The Peer Review process consisted of providing an information packet to members of the Panel in advance of convening the panel for the Panel members to become acquainted with the corridor and with the HOV analysis. Peer Reviewers were escorted on a peak-period tour of the corridor (a videotape was supplied to Panel members who were not present in Vancouver) and the participated in a roundtable discussion with the Technical Advisory Committee.

The Peer Review Panel consisted of:

Luisa Paiewonsky, Massachusetts Highway Department. Luisa was involved with the planning and implementation of a reversible HOV lane in Boston, Massachusetts, and is currently involved with its operation.

Koorosh Olyai, Dallas Area Rapid Transit. Koorosh oversees the operation of all Dallas-area HOV lanes for DART, including the reversible HOV lane on I-30.

Chuck Fuhs, Parsons Brinckerhoff. Chuck is a considered a national HOV expert in the planning and design of HOV systems, and has served as Peer Reviewer for the current northbound I-5 HOV lane.

Roger Johnson, HDR Engineering. Roger formerly worked for WSDOT where he was involved with planning and implementation of the Puget Sound regional HOV system

PHASE I PEER REVIEW

The Technical Advisory Committee met with the Peer Review Panel at their September 15, 1999, meeting. The following are notes from the first Peer Review Panel.

Boston

This consists of a reversible 6-mile-long HOV lane built in 1995 that operates in the AM and PM peak periods for two or more persons. The reversible HOV lane merges into general purpose lanes at the end. There are four general purpose lanes in each direction. Highlights are:

- No increase in accidents as result of project even though no median shoulder and narrow corridor (about 14 feet total for lane and shoulders) – incidents where vehicles strike the movable barrier are similar to accidents with median barrier with no movable barrier
- Some incidents have occurred at beginning crossover but no major increase
- Enforcement is done by “rejection areas” – violators waved over by police
- 1.4 incidents per month
- Takes 1 hour and 10 minutes to move the barrier, use two trucks for logistics
- Limited number of access points
- 1,000 vehicles per hour in HOV lane
- HOV lane merges into LOS F conditions
- 5-minute merge delay in PM

- Few delays in AM
- 5-7 minute HOV travel time savings
- About 120 buses per peak period
- Concerns about substandard design have gone away
- No increase in incidents
- 55 mph posted speed
- Perceived travel time savings about twice actual
- O&M costs about $650,000 per year, all inclusive
- Used CMAQ for first three years to fund O&M, now using STP
- Some controversy at start of planning on two facilities, some complaints about underutilization; marketing campaign at start of operations helped, and enforcement is seen as a key to success
- Massachusetts Hwy. Dept. received design waivers for substandard design, OK because of current geometric conditions and potential air quality benefits as well as air quality improvement requirements.

Dallas

This is a reversible peak-period HOV lane that opened in 1991 on I-30. The HOV facility is concurrent flow, separated by a double white line buffer (3-4 feet wide), broken for legal access at a limited number of locations. Highlights are:

- 17,000 persons per day over 6 hours (3 in a.m., 3 in p.m.)
- 47 buses per peak hour, 60/40 carpool/bus person split
- 1,200-1,400 vehicles per hour in HOV lanes
- Two barrier moving machines
- Incident management includes on-site tow trucks, heavy duty in case they need to tow buses
- No entry delay, endpoint merges into a paved shoulder with general purpose lane
- Transit agency enforces the lane and operates the lanes
- 1% violation rate on contra-flow lane, 4-5 percent on concurrent flow lanes
- ¼-mile section with no shoulder with curves and a grade; no safety issue
- O&M cost $80,000 per month including barrier moving machines
- No federal operating assistance
- Travel time savings: actual 14-15 minutes for HOV users, perceived about 29 minutes
- HOV lane opened to GP traffic during major incidents
- 48 incidents per month on average (includes vehicle breakdowns, out of fuel, accidents, etc.)
- Usage 39 percent about forecasts, 5-6 percent increase over last 20 months, 143-240 percent increase over baseline conditions (1991)
- Travel time savings is also a savings in bus O&M costs – about $120,000 per year
- Very few buses on I-635 HOV lane – about eight peak-hour buses but lots of carpools

Seattle

- SR 520 is inbound only in the AM toward Seattle, ends at foot of Lake Washington Bridge
- 3+ HOV restriction
- Uses outside shoulder
- Stripe separation from GP lane
- No public perception of safety problems

- Enforcement by motorcycle patrol. HERO program has phone number where people can report violators (will receive educational material in the mail – no ticket).
- WSDOT has 15 percent cap on violation rate – saturation enforcement when violation rate exceeds cap
- 70-80 percent continued public support

Experiences

- Slightly elevated accident rate on I-93 probably due to 6-inch raised berms separating the GP and HOV traffic. HOV lane open to GP traffic in non-peak hours. The Boston HOV lane has no shoulder, four incident management areas, and has worked well. Good public support. Commuters say lane should be longer due to queues.

- The Dallas HOV facility has 75 percent support from all users on I-30. Ridership increases about 6-8 percent per year. Only naysayers are committed GP users.

- In Seattle, HOV lane system as it was constructed has discontinuous segments. The system worked but was not desirable. One direction HOV facilities may work for both inbound and outbound trips (such as the SR 520 lane in Seattle).

Safety

In Boston, in the 1970's they had a contra-flow HOV lane separated by pylons from opposing direction of traffic. The program was ended when a maintenance worker was fatally injured setting up pylons.

High-Capacity Transit Sharing HOV Corridor

The question was asked of the Peer Reviewers whether a high-capacity transit system and HOV could operate in the same corridor. In Boston, HOV and commuter rail share the same corridor. There is very little competition, as the corridor is so congested commuters welcomed the choice of modes. Enhanced bus service and visible carpools make the HOV lane successful. DOT and transit agency worked closely together during the planning stage due to transit concerns about competition from HOV lane.

In Dallas, studies have shown that LRT and bus/HOV riders are not the same market. HOV brings in longer trips than LRT.

HOV and Transit Base

In Boston, there were no specific transit service improvements tied to the HOV lane. There has been a 10-15 percent increase in buses due to increased ridership over 4 years. Bus on-time service performance has improved with the HOV lane.

In Dallas, there was no significant increase in bus service tied to opening of HOV lanes. One more Park-and-Ride facility was added before the HOV lane opened on the I-30 corridor. Bus loading has increased but there has not been a service increase.

TAC Questions

Is there a sole-source issue with the movable barrier equipment supplier? In Boston, they sought a waiver for sole source but were denied – agency purchasing department thought there may be some R&D at time of bid notice that may result in more systems. This did not happen, but they did receive a good bid price on concrete.

TAC Discussion

PM peak contra-flow lane may be problematic due to the impacts on southbound traffic.

A check of accident history is also needed at the north end of the Interstate Bridge in the curve section – see if barrier there has been hit.

The TAC recommended dropping the permanent barrier option on the bridge, but kept a pylon separation option. Need more analysis. Consider pylon separated lane in AM only.

Still keep both 2+HOV and 3+HOV options in Washington.

The Peer Review Panel and the TAC discussed the three promising HOV strategies, which include:

- **Full Corridor Option**: HOV lanes from 134th Street in Washington to approximately Lombard Street (southbound) or Going Street (northbound) in Oregon including a reversible HOV lane, utilizing a fixed barrier across the Interstate Bridge and a movable barrier through Delta Park.
- **Delta Park Option**: A reversible HOV lane only in the portion of the corridor where the existing northbound HOV lane is located (southbound the HOV lane would end near Lombard Street).
- **Queue Bypass Option**: The addition of an AM peak southbound HOV lane in Washington similar to the current PM northbound HOV lane in Oregon. Further analysis is needed to determine if the HOV lane can be re-started on the Oregon side of the Interstate Bridge in the AM peak and on the Washington side in the PM peak.

TAC Discussion

The Peer Review Panel discussed the Interstate Bridge HOV options shown in **Table 14**. The discussion regarded the impacts of barrier separation on the bridge and also the impacts of the contra-flow HOV lane on the non-peak travel direction.

Barrier Separation

A movable barrier on the Interstate Bridge was determined earlier in the process to be infeasible due to the following reasons:

- The lift span cannot lift the weight of a barrier
- During lifts, the barrier must be disconnected at the lift span and then reconnected after the lift is completed, resulting in longer closure times during bridge lifts
- Movable barriers may shift during bridge lifts, resulting in a need to mobilize equipment to replace the barrier in its pre-lift location

The TAC asked that further analysis be given to using a concept of removable pylons, or "candles," as lane separators for the reversible HOV lane. Two other locations on the west coast where reversible lane configurations without fixed barriers are used to create reversible lanes are the Golden Gate Bridge in San Francisco (movable pylons) and the Lion's Gate Bridge in Vancouver, British Columbia (lane control signs).

Impacts to Non-Peak Traffic

A reversible HOV lane on the bridge is gained by taking a lane in the opposing (non-peak) direction of traffic and converting it to a peak direction HOV lane. This would entail taking a lane on the northbound bridge structure during the AM peak period (7-9 AM) and converting it to a southbound HOV lane, and in the PM a lane on the southbound structure would be converted to a northbound HOV lane during the PM peak period (3-6 PM).

In examining the year 2020 modeled volumes, the northbound hourly volume in the AM peak is approximately 2,400 vehicles per hour (1,200 vehicles per hour per lane), which can be accommodated within two travel lanes (capacity approximately 1,300 vehicles per lane per hour).

In the PM peak, however, southbound volumes currently exceed 3,400 vehicles per hour (1,700 vehicles per lane per hour) with an estimated capacity of 3,200 -3,400 vehicles per hour (1,600 to 1,700 vehicles per hour per lane), and the 2020 volumes are higher (over 4,500 vehicles per hour). This would result in LOS E conditions for the non-peak direction of travel. Short-term mitigation would consist of using the SR 14 westbound ramp meter, but it is likely that in 2020 this situation may result in a worsened overall level-of-service. Potential mitigation measures to be explored include upstream metering of southbound traffic in the PM peak (especially at the SR 14 and SR 500 on-ramps, and also considered at Mill Plain, Fourth Plain, Main Street, and 78th Street to reduce the potential for traffic diverting from other ramp meters to non-metered ramps) or measures to encourage through traffic southbound to use I-205 (variable message signs, overlegal permit routing requirements, reconfiguration of I-5/I-205 junction).

Two southbound analyses were run for the PM peak period: No New HOV (which would continue to have three general purpose lanes southbound across the Interstate Bridge) and Full Corridor HOV (two general purpose lanes southbound across the bridge). The results of the FREQ model run for the PM peak southbound analysis are attached. The impact of taking a southbound lane in the PM peak would be to create a queue that would extend up to 99th Street by 6 p.m. This would corroborate the TAC's recommendation.

There are examples of other HOV lane projects which do not continue across a major bridge crossing. In the Northwest these include the current HOV lane on I-5 in Portland and SR 520 in the Puget Sound region.

TAC Action

The TAC made the following preliminary recommendations at the September 15 Peer Review meeting.

- The permanent barrier option on the bridge is to be dropped, however, continue to examine a pylon separation option
- A northbound, reversible HOV lane across the bridge should not be considered for the PM peak.
- Continue to consider an AM peak reversible HOV lane on the bridge.
- Continue to analyze both two general purpose +HOV lane and three general purpose + HOV lane options in Washington.

Table 14. I-5 Bridge Alternatives
Peer Review Discussion

	Pros	Cons
Alt. 1: Contra-flow lane with Permanent Barrier (with flow GP in off-peak period)	• Adds peak direction lane • Easy to enforce • Will work on lift bridge	• Safety: oversized trucks, motorist confusion, signing, barriers that separate GP lanes • Incidents: increase likely, stalled vehicles block #1 lane • C-TRAN cannot access downtown Vancouver without out-of-direction travel
Alt. 2: Contra-flow lane with pylons (only is deployed during peak periods)	• Low cost and rapid implementation time • Works with limited bridge width • No width needed for opposing separation • Easy to enforce	• Safety: deployment crew exposure, exposed barrier ends, potential head-on accidents • Reduced speed limits for all lanes, probably 45 mph • Requires daily deployment crew • Could require annual operation budget of approximately $500k • C-TRAN cannot access downtown Vancouver without out-of-direction travel
Alt. 3: HOVs in mixed flow on bridge	• Same as current operation • Can work with HOV lanes on either side • Compatible with C-TRAN buses to Vancouver	• No bus/HOV benefits over bridge • Can create new queues if HOV lanes terminate on either side

These alternatives do not include other approaches including contra-flow lane with moveable barrier which has already been eliminated as infeasible over the lift span.

Examples where above alternatives have been applied:

- Alt. 1: Not applied on any freeway to separate concurrent general purpose lanes. This strategy has been widely applied as a tool for temporary traffic management on construction projects where lanes are split around construction work zones. Permanent barriered single HOV lanes are located in Houston (I-45, US 59, I-10); Dallas (I-35E), but these are not open to general purpose traffic.
- Alt. 2: New York region on I-495 Long Island Expy, Route 495 to Lincoln Tunnel in NJ, and Gowanus Expy in Brooklyn.

PHASE II PEER REVIEW

The Technical Advisory Committee met with the Peer Review Panel at their November 16, 1999, meeting to conduct the second Peer Review.

The second peer review focused on addressing the issues regarding the Interstate Bridge, the reversible lane concept in Delta Park, HOV treatments in Washington, and the results of the public opinion survey. There was also discussion about policy and public opinion implications of implementing HOV lanes, including the reversible lane concept. Detailed analysis, including modeling, was presented for consideration.

Subsequent to the previous peer review, further review and meetings with RTC and the two DOTs have resulted in continued safety concerns with the lack of physical traffic separation afforded by pylons, as well as design aspects where the current fixed barrier would be permanently removed at the transition areas and replaced with pylons that would open and close the reversible lane (a gate option is unlikely due to the length of the transition area) and it is likely that the pylon-only option will be dropped. At this point, there are two options that appear to be viable for the bridge:

- Movable barrier the entire length of the reversible lane, with a 270-foot gap on the lift span where movable pylons would be placed during contra-flow operations. The barrier would be moved against the inside bridge barrier, resulting in a loss of 2 feet from the current 36- to 37-foot travel surface, during other times of the day and the pylons would be removed.
- Movable barrier the entire length of the reversible lane, including the lift span. When the HOV lane is closed, the barrier on the bridge segment would be towed off of the lift span and stored elsewhere (not on the lift span), and the remainder of the barrier would be stored against the inside bridge barrier. An agreement would be needed with the Army Corps that no bridge lifts would occur from 6-9 AM on weekdays.

The Peer Review Panel was notified of the study's need to recommend preferences on the following:

1. Bridge crossing options for both AM and PM peaks: no HOV lane, or reversible HOV lane (plus confirming the preliminary TAC recommendation eliminating a northbound PM peak reversible lane)
2. If a reversible HOV lane is recommended, the type of separation (movable barrier plus pylons, movable barrier along the full length of the bridge with agreement not to lift the bridge between 6 and 9 AM)
3. Washington lane configurations north of Main Street (2 GP plus HOV or 3 GP plus HOV)

The Peer Review Panel reviewed these options and reached some conclusions that allowed the TAC to eliminate alternatives and eventually recommend a selected HOV alternative. The Peer Review Panel responded directly to the following questions:

- What are the safety and incident management experiences with a reversible HOV lane across the Interstate Bridge, using the options stated above?

- What considerations should be given to the number of lanes on the Washington side (3 GP lanes plus HOV or 2 GP lanes plus HOV), especially given the FREQ results included in this packet?
- If HOV lanes are used as queue bypasses, can the lane be restarted after crossing over the Interstate Bridge? Is there a minimum length of the queue bypass for HOV to be effective? (For example, the Delta Park southbound HOV option would be less than 2 miles in length).
- What are your thoughts about the HOV alternatives if the Interstate Bridge is replaced and the bottleneck there is removed?

Given the results of the modeling which indicated a significant impact to southbound (non-peak) traffic in 2020 with a PM peak reversible HOV lane northbound, and given the difficulties with the narrowness of the bridge structures as well as the impracticalities of designing such a movable barrier, the Peer Review Panel recommended, and the TAC agreed, to remove reversible HOV lanes on the Interstate Bridge from further consideration.

The Peer Review Panel agreed that an opening year analysis will help resolve the lane configuration issues. At this point, there was not enough difference in the 2020 analysis between the 3GP plus HOV and the 2GP plus HOV configurations to make a clear determination that one option was preferable over the other.

The Peer Review Panel did point out that other areas, including the Puget Sound region, have experienced an HOV system evolution that has occurred over time. Thus, they believed that queue bypasses that began on one side of the bridge could be continued after crossing the bridge, provided that congestion levels and HOV time savings were sufficient to warrant the continuation of the HOV lane. However, there is no reason that a Washington-only or Oregon-only queue bypass could not work for the interim.

Replacing the Interstate Bridge is a significant, regional priority decision and has significant implications on the corridor. If the bridge is replaced, then it is likely that HOV could be implemented in a bi-state manner.

NEXT STEPS

Resolution of Remaining Policy Issues

There are remaining policy issues that need resolution. These are detailed below.

- *Time-of-Day of HOV Operation:* ODOT allows for peak period, weekday HOV operation while WSDOT requires HOV lanes to operate 24 hours a day, 7 days a week. The consultant recommendation was to consider a peak period HOV system, given Trade Corridor considerations as well as off-peak utilization. However, the Washington Transportation Commission has been reluctant to deviate from the 24-hour policy. The Washington Legislature in 1998 considered legislation to allow peak period HOV operation but did not pass this legislation.
- *HOV Operations – Enforcement and Incident Management:* Both enforcement and incident management are significant, ongoing expenses for both states in implementing HOV. For future HOV lanes that cross the Columbia River, bi-state agreements need to be reached regarding HOV enforcement and incident management responsibilities.
- *WSDOT Approvals:* If HOV is implemented on I-5 by restriping to a 3 GP plus HOV configuration southbound, this will result in narrow left-hand shoulders (4 feet in width). Design deviations will need to be approved by the WSDOT Olympia Service Center. Based on experience, deviations to install an HOV lane are easier to obtain as compared to deviations to install a (third) general purpose lane.
- *ODOT Approvals:* Design of HOV southbound through Delta Park requires resolution of design issues to determine how an HOV through Delta Park should be implemented as part of major widening through Delta Park. ODOT would need to approve the design of any HOV implementation on I-5 south of the Interstate Bridge.

Implementation

- *Funding:* Washington and Oregon need to agree on an HOV implementation project and begin programming funding for this project. Funding priorities would need a multi-agency approval process, including the Washington and Oregon Transportation Commissions, RTC, and Metro.
- *HOV Implementation:* The timing of construction, how the lane is implemented, and the marketing of the HOV lane need extensive discussion and agreements prior to opening day.

BI-STATE DECISION-MAKING ISSUES

RTC was the project lead for the overall study and the management of work tasks. The I-5 HOV Technical Advisory Committee provided expertise and comment on the technical analysis and was made up of staff from the Washington State Department of Transportation, City of Vancouver, Clark County, C-TRAN, Metro, and the Oregon Department of Transportation. In addition, the two state transportation departments provided expert advice regarding the operation, design, and characteristics on HOV and their state facilities. Findings and recommendations of the TAC were forwarded to the Regional Transportation Advisory Committee for their comment and review prior to consideration by the RTC Board.

As a bi-state transportation project, the implementation of an I-5 HOV facility requires a mutual recommendation among the bi-state jurisdictions. **Figure 19** depicts the decision-making process. The Bi-state Transportation Committee, created by joint resolution of the RTC Board and Metro in May of 1999, is charged with reviewing all issues of bi-state significance for transportation and presenting any recommended action to RTC and JPACT. The Intergovernmental agreement between RTC and Metro states that JPACT and RTC Board, "shall take no action on an issue of bi-state significance without first referring the issue to the Bi-state Transportation Committee for their consideration and recommendation." The RTC Board was being asked to forward the findings of the I-5 HOV Operational Study to the Bi-state Transportation Committee for their discussion and recommendations.

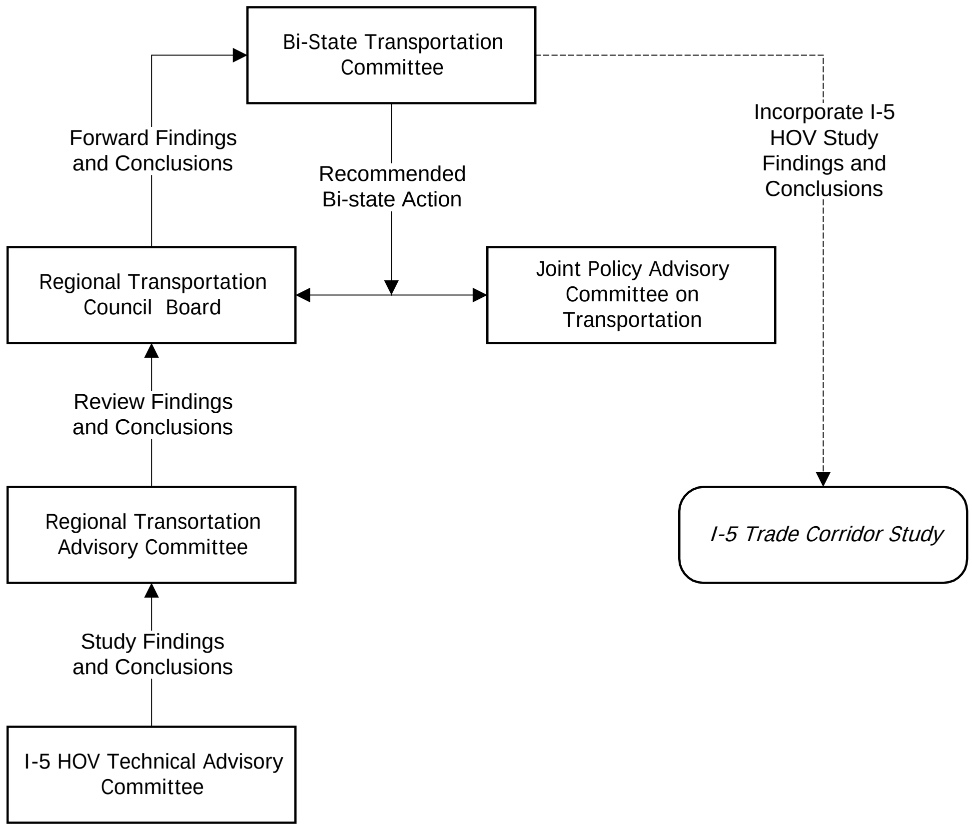
The RTC Board received the study finding and conclusions and forwarded them to the Bi-State Transportation Committee for their discussion. The role of the Bi-State Transportation Committee was to consider the study findings and conclusions and to recommend any bi-state action to the RTC Board and Joint Policy Advisory Committee on Transportation (JPACT) regarding an HOV facility in the I-5 corridor. Study findings will be forwarded to the I-5 Trade Corridor Study.

SUMMARY OF TRANSPORTATION POLICY ISSUES

This section summarizes the key policy issues associated with the I-5 HOV Operational Study.

- The study findings are consistent with the adopted MTP and the Clark County HOV Study (December 1998). The MTP calls for providing the highest level of transportation services and mobility in a cost-effective manner and with minimum environmental impact. The MTP also recognizes the recommendations of the Clark County HOV Study. The study recommendations were adopted by the Board and include Clark County HOV goals and policies and a Clark County HOV System Plan. Recommendations also called for examination of opportunities for implementation of HOV in the I-5 corridor.
- The implementation of an I-5 HOV facility will require bi-state consensus. Issues of bi-state significance should first be referred to the Bi-state Transportation Committee for their consideration and recommendation. The RTC Board is being asked to forward the findings of the I-5 HOV Operational Study to the Bi-state Transportation Committee. The study findings should be advanced through the decision-making process, including the I-5 Trade Corridor Study.
- The study findings should be considered in the context of the current I-5 widening construction project construction project between 99th Street and SR 500. Study findings will provide guidance to WSDOT regarding the use of new lane capacity being constructed.
- The I-5 HOV Operational Study identifies HOV as a viable High Capacity Transit (HCT) strategy for the I-5 Corridor, but does not address the HOV in the corridor with an Interstate Bridge replacement. The I-5 Trade Corridor Study is the vehicle for development of a long-term improvement plan for the I-5 Corridor. The I-5 Trade Corridor Study should address the long-term role of HOV in the corridor in the context of new bridge capacity. The Delta Park widening discussion should include findings of the I-5 HOV Operational Study and identify the relationship between a reversible HOV lane in Oregon and the Delta Park widening project.
- The I-5 HOV Operational Study findings are consistent with WSDOT HOV policy regarding travel time savings, lane use, added capacity for HOV and segment length. State policy calls for full time HOV lane operation. However, the study recommends peak-period-only HOV in the I-5 corridor.

Figure 19. Decision-Making Process



This Page Intentionally Left Blank

PROJECT OUTREACH AND PUBLIC INVOLVEMENT SUMMARY

Technical Advisory Committee

The study's Technical Advisory Committee (TAC) provided technical review and advice to the project. The TAC consisted of:

- Regional Transportation Council – Bob Hart, facilitator and Dean Lookingbill
- WSDOT: Gary Westby and Les Rubstello
- ODOT: Dan Layden and Dennis Mitchell
- C-TRAN: Michael Haggerty
- City of Vancouver: Matt Ransom and Kevin Wallace
- Clark County: Kevin Gray
- Metro: Chris Deffebach

The TAC met ten times during the study. Early meetings consisted of brainstorming, developing a range of HOV alternatives, and discussing and addressing physical issues in the I-5 corridor. Two Peer Reviews were conducted as part of TAC meetings. The TAC reviewed and provided comments on the consultant recommendations.

Public Process

The project team looked to stakeholders for informed input into the project in a number of ways including open houses, media outreach, and a random sample survey of Clark County residents and bi-state travelers. Additionally, the project team held regular technical advisory committee meetings with agency stakeholders and partners.

OPEN HOUSES

The project team held three open houses during the project at the Vancouver Housing Authority. Each open house focused on specific decision-making points in the project. The open houses were publicized through local calendar advisories and media outreach targeted at *The Columbian* and *The Oregonian.*

The HOV project team, comprised of the Southwest Washington Regional Transportation Council, Parsons Brinckerhoff, David Evans and Associates, C-TRAN, WSDOT, ODOT, and Pacific Rim Resources, conducted the open houses to update residents on the project, and to gain opinions regarding the installation of an HOV lane on portions of I-5. Project team members were available to answer questions and information stations added a graphic element to the open houses.

Open House #1, August 26, 1999

About 25 people attended the first open house, which provided HOV background information, I-5 HOV Operational Study information, and a timeline indicating the next steps in the study process.

Participants recorded their concerns and comments through questionnaires distributed at the event. The questionnaire asked attendees to comment on HOV lanes and various implementation options. Attendees also had an opportunity to comment on the format and effectiveness of the open house. Of those who responded, the most common issues included:

- Concerns about “cheating” on HOV lanes
- Concerns about existing traffic congestion
- Needed expansion to the existing capacity (though, not necessarily with HOV)
- Concerns about potential bottlenecks occurring where the HOV lanes end
- Concerns about congestion worsening on general purpose lanes with the addition of HOV lanes
- The inclusion of other modes (bus and light rail) into HOV planning

Open House #2, November 4, 1999

About 18 people attended the second open house. In addition to providing general project background information, the open house focused on the project team’s efforts to narrow alternatives for further analysis. Displays presented four alternatives for consideration. Project team members were available throughout the open house to answer questions and provide information about each of the alternatives. Several comments supportive of HOV were recorded at the stations. Concerns about HOV included a reiteration of general concerns expressed at the first open house. Several attendees also expressed safety concerns about alternatives that included a moveable barrier across the Interstate Bridge.

Open House #3, December 8, 1999

The final open house was attended by about 15 people who viewed displays and maps depicting details of the project team’s selected alternative for further analysis. The open house also featured general background information, random sample survey highlights and a modeling demonstration. As with previous open houses, project team members were available to answer questions and provide information. Attendees were split as to whether they favored or opposed the HOV concept. Among those who agreed with the HOV concept, the selected alternative was viewed favorably. Recorded comments included a suggestion that the project team should consider recommending transportation rewards for living in inner Vancouver and a caution not to encourage suburban sprawl.

Public Opinion Survey

I-5 HIGH OCCUPANCY VEHICLE LANE
SURVEY HIGHLIGHTS AND CONCLUSIONS

The Southwest Washington Regional Transportation Council (RTC), in cooperation with the Washington State Department of Transportation, recently conducted a survey of Clark County residents, seeking viewpoints on HOV lanes and other Clark County transportation issues. The statistically valid telephone survey sampled 800 Clark County residents. The survey data provided representative data on attitudes, knowledge, and behaviors regarding high-occupancy vehicle (HOV) lanes. This survey was conducted in November 1999.

The survey sample was designed to ensure that those most likely affected by HOV lanes were adequately represented. Of the 800 surveyed, three-quarters of the sample were taken from within the I-5 corridor and one-quarter from the remainder of Clark County. The survey sample also ensured that at least half of the respondents were bi-state travelers.

Almost two-thirds (62%) of the respondents agree or strongly agree that traffic congestion is a serious problem.

Travel Behavior (asked only of the bi-state travelers)

Detailed cross-tabulations are contained in the Technical Appendix, along with the full survey report.

Almost all bi-state travelers (96%) are aware of the existing I-5 HOV lane. Most of the respondents report they used the lane at least three times a week; some of these apparently used the lane in non-peak hours. The most common state used of the HOV lane is work (68%), followed by travel for social/recreational activities (13%), and shopping (13%).

Two-thirds of the bi-state travelers who use the existing I-5 HOV lane report saving travel time: either 6 to 10 minutes (30%) or 11 to 20 minutes (36%). In order for people who do not currently use the lane to use it, a time savings of at least 6 to 10 minutes (16%) or 11 to 20 minutes (19%) would be required.

More than a quarter (26%) report that they would not use the lane regardless of how much time was saved.

Of those who don't use the existing I-5 HOV lane, the major reasons include:

- Not being able to find a carpool partner (40%)
- Not being able to adjust their schedule to carpool or taking the bus (22%)

Attitudes about HOV Lanes

When discussing HOV lanes, slightly more than 50 percent agree or strongly agree that HOV lanes are an effective strategy to managing bi-state traffic congestion. Another 18 percent are neutral, while 32 percent disagree or strongly disagree that HOV lanes are an effective strategy.

HOV lanes receive a far less favorable response if an existing lane is converted to HOV. About 58 percent disagree or strongly disagree that this should be done. However, 65 percent agree or strongly agree that a new HOV lane should be provided by adding a new lane.

Of those sampled, two-thirds (66%) agree or strongly agree that HOV lanes should operate only during morning and evening rush hours and directions. (Only 23 percent agree or strongly agree that they should operate 24 hours a day, seven days a week.

The vast majority (80%) of respondents agree or strongly agree that HOV lanes should have a strong enforcement program.

Conclusions

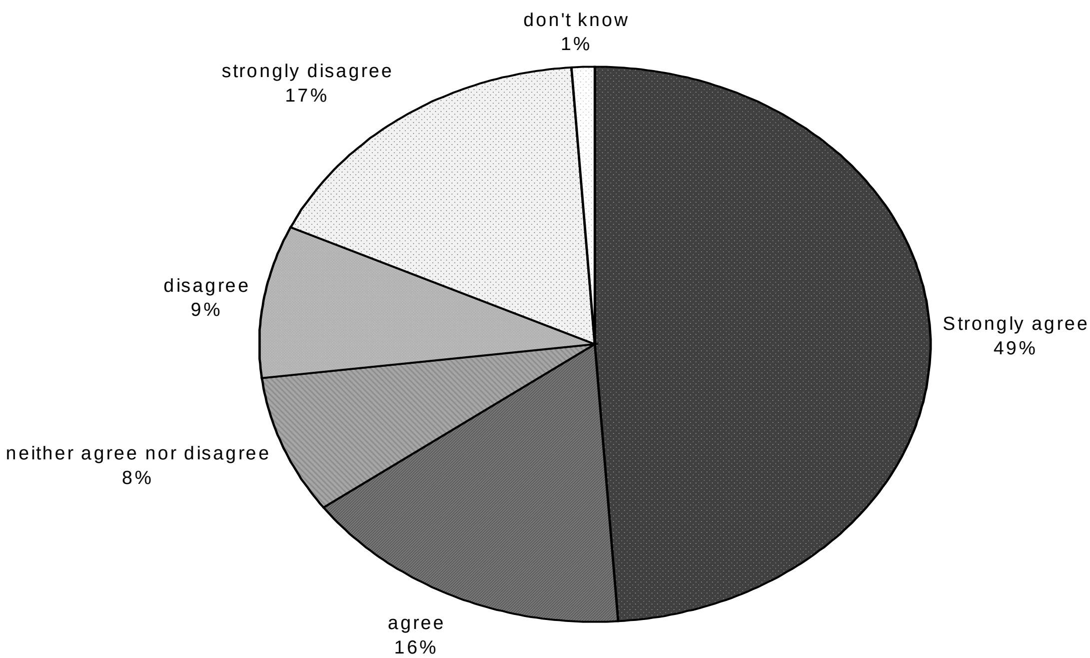
The results of this survey should be included for consideration when selecting a preferred alternative. The results also provide valuable baseline information that can be used in formulating a marketing plan, should implementation occur. The survey shows clear preferences that should be highlighted if included as part of a selected alternative. Notably:

- The HOV lane concept in Southwest Washington is more acceptable when HOV lanes are added as new lanes.
- The HOV lane concept in Southwest Washington is more acceptable when operating during peak periods only.
- Travelers overwhelmingly prefer a strong enforcement program in conjunction with the HOV lane implementation.

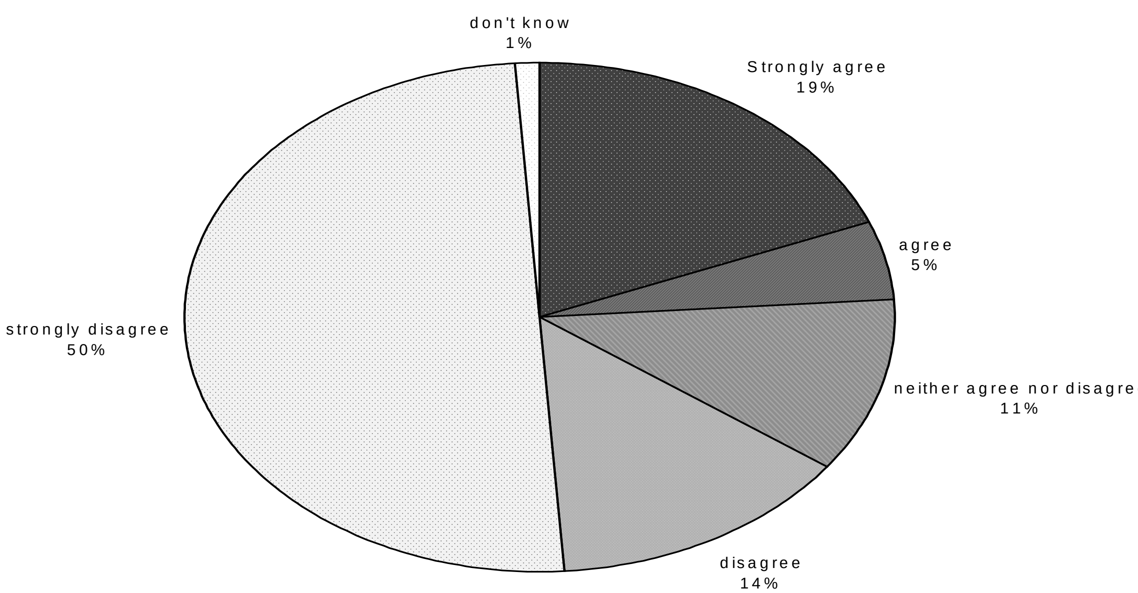
HOV lane awareness is currently high in the corridor. However, awareness will have to be readdressed for a southbound lane introduction. An awareness campaign should take advantage of traveler familiarity with the northbound HOV lane. RTC should continue to work with WSDOT, ODOT, C-TRAN, and Tri-Met in pursuing the awareness campaign and joint marketing opportunities.

Marketing opportunities to reach HOV user markets (shoppers, event attendees, commuters) should be more fully considered as part of an implementation plan. Targeted campaigns should highlight time savings opportunities. HOV awareness also should be pursued in conjunction with carpool and transit program marketing.

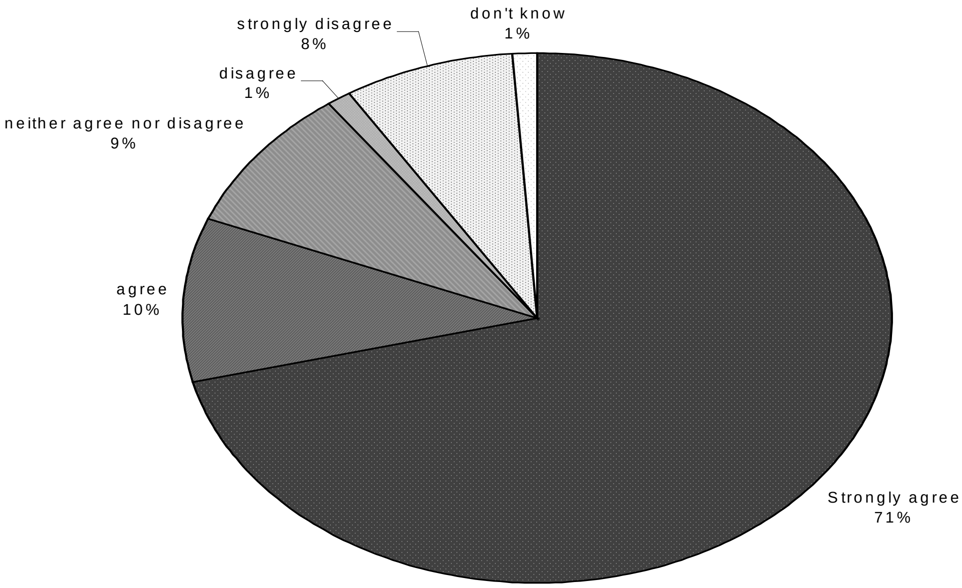
HOV Lanes Should Operate During Peak Periods Only



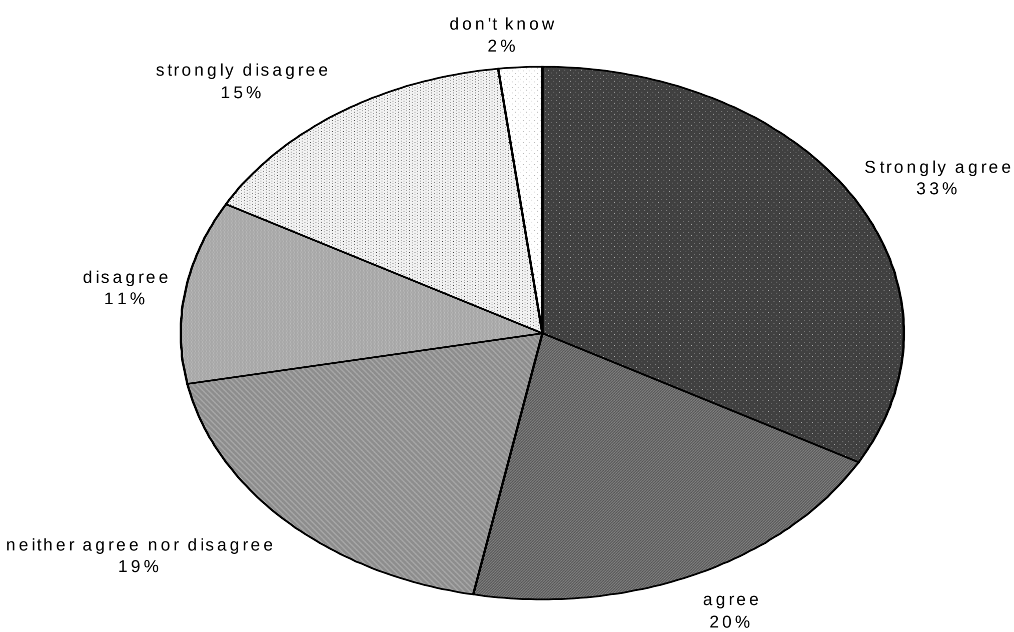
HOV Lanes Should Operate 24 Hours a Day, 7 Days a Week



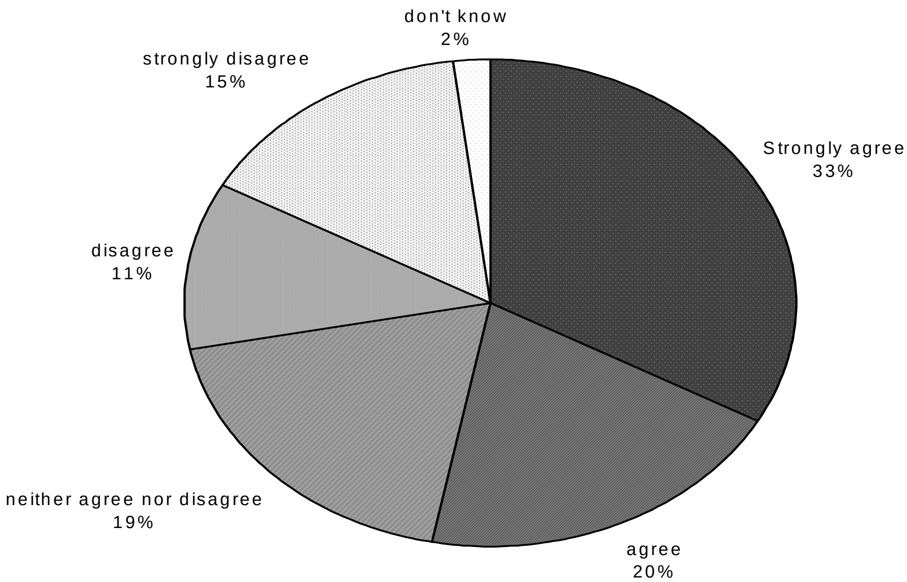
HOV Lanes Should be Strongly Enforced



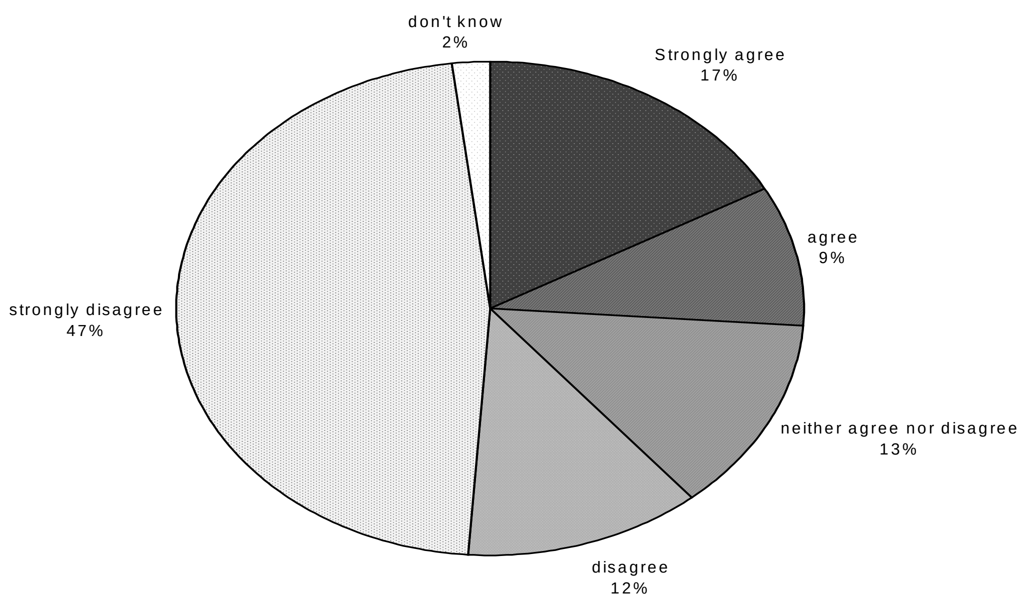
HOV Lanes are Effective in Managing Congestion



A New I-5 HOV Lane Should be Added Instead of Converting a Lane



A New HOV Lane Should be Provided by Converting and Existing Lane



This page intentionally left blank.